Agriculture Canada
Canadian Grain Commission

Agriculture Canada
Commission canadienne des grains

GRAIN RESEARCH LABORATORY

1986-1987 REPORT

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1986 - 1987 REPORT
of the
GRAIN RESEARCH LABORATORY
60th Report

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Cover Photo
Introducing a ground wheat sample into a NIR instrument for rapid determination of protein content.

CANADIAN GRAIN COMMISSION
GRAIN RESEARCH LABORATORY

August 26, 1987

Canadian Grain Commission
Winnipeg, Manitoba

Commissioners:

I am pleased to submit the following report reviewing the activities of the Grain Research Laboratory for the period April 1, 1986 to March 31, 1987.

Respectfully submitted,

K.H. TIPPLES
Director

DIRECTOR'S COMMENTS

The Grain Research Laboratory's work during 1986-87 has continued to serve two primary objectives: quality assurance for Canadian grains and oilseeds, and market support.

A severe slump in world grain prices during the past year has caused increasing financial difficulties for Canadian producers. Fortunately, Canada's continued commitment to quality has been a major factor in maintaining markets through this difficult period. The marketing situation was not helped by a second successive wet harvest in 1986, which reduced the amount of top grade grain available for export and again made it very difficult to obtain representative samples for our new crop surveys.

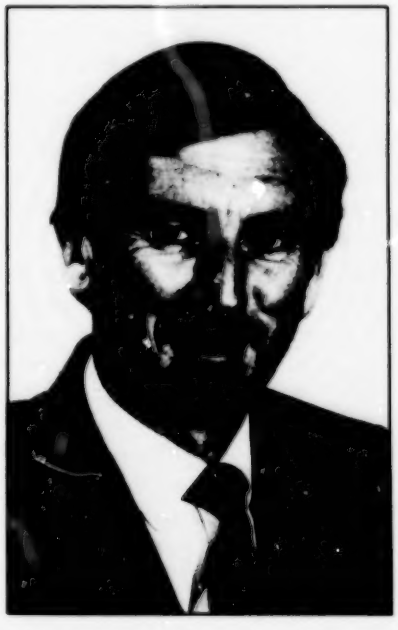
Additional wheat monitoring work during the year was devoted to testing carlot and cargo samples for alpha-amylase activity, using the Hagberg Falling Number method. A new instrument, the paste viscosity indicator, has been designed and built at the Grain Research Laboratory for possible installation in terminal elevators. A prototype instrument is currently being evaluated under operational conditions to determine relative advantages compared with the Falling Number method.

A general endorsement by grain producers of Canada's commitment to high quality varieties resulted in a marked reduction in the growing of non-registered varieties of inferior quality. This led to a concomitant reduction in the level of operational varietal identification service that the Grain Research Laboratory was asked to provide for the Grain Inspection Division. Notwithstanding, the Laboratory has continued to give high priority to research on development of new and improved techniques for non-visual varietal identification. To date, however, there is little indication that Canada will be able to remove the kernel distinguishability requirement for new wheat and barley varieties for some considerable time to come.

In general, the Laboratory's research programs continue to seek a better understanding of what constitutes "quality" in cereal grains and oilseeds. In collaboration with marketing agencies, notably the Canadian Wheat Board, our scientists have continued to travel widely in existing and potential market areas; and the information obtained has helped us to update our understanding of our customers' definition of "quality" and of what classes and grades of Canadian grain may be best suited for a given end product. Ongoing efforts are made to develop improved methods of quality analysis based, wherever possible, on rapid instrumental approaches. This year's Annual Report contains a special article featuring the work of GRL scientists on application of near-infrared reflectance spectroscopy to rapid measurement of various quality parameters.

The Laboratory has continued to play an active role in development of meaningful international standard methods for quality tests of cereals and oilseeds through involvement with such organizations as the International Association for Cereal Science and Technology (ICC), the American Association of Cereal Chemists (AACC) and the International Standards Organization (ISO).

A summary of our research activities during the past year is presented in the body of this report covering the fiscal year April 1, 1986 to March 31, 1987.



K.H. TIPPLES
Director

QUALITY ASSURANCE AND MARKET SUPPORT FUNCTIONS OF THE GRAIN RESEARCH LABORATORY

The Grain Research Laboratory (GRL), a division of the Canadian Grain Commission (CGC), was established in 1913 by the Board of Grain Commissioners for Canada "for the study of problems relating to the grain trade". At the outset, Laboratory experiments related to two principal subjects, the grading of grain and excess moisture in grain. The early moisture work concerned methods of determining moisture content of grain and the relation between grain moisture and its tendency to heat. These studies provided valuable information on safe moisture levels for the storage of Canadian wheat. Early grading studies primarily involved milling and baking quality evaluation of new crop grade composites, the first series of samples representing wheat from the 1913 and 1914 harvests. Other experiments at that time involved determination of proper temperature limits for the safe drying of wheat containing excessive amounts of moisture and studies into the effect of various forms of damage on milling and baking quality. The deleterious effects of such factors as "frosted, green, bleached, soft and dark kernels" were evaluated and reported by the year 1920.

The concern of the Board of Grain Commissioners with the quality of wheat varieties was emphasized by experiments to determine the relative milling and baking values of Marquis and Red Fife, the two best-known predecessors of our present-day high quality bread wheat varieties. The early history of the GRL also reveals that the major thrust of work then (new crop surveys, varietal evaluation, moisture measurement and grading studies) bears a remarkable resemblance to today's objectives.

The Laboratory today functions within the terms of reference of the Canada Grain Act. Section No. 12 states that the Commission shall "undertake, sponsor and promote research in relation to grain and grain products and, in so doing, maintain an efficient and adequately equipped laboratory". The strategic objectives for the Laboratory operations all relate to this specific objective of the Commission.

The work of the Laboratory may be arbitrarily considered under three different categories: "research"; "related scientific activities"; and "provision of scientific and technical expertise". These three categories of operation are all inter-related. The CGC must respond to problems and questions on quality and the Laboratory is expected to provide appropriate expert advice. In order to do so, the GRL must have a base of scientific and technical expertise and this is provided by the research work performed. "Related scientific activities" involve such programs as new crop surveys, cargo and carlot monitoring and new variety evaluation. The scientific and technical expertise is required to carry out meaningful surveys, and research is needed to both understand better what "quality" is and also to develop new and improved methods of measuring quality. The excellence of the research at the GRL and the international reputations achieved by its scientists lend credibility to the survey data published and to the expert advice provided by the GRL to the grain industry.

All GRL activities serve one or both of two very clear basic objectives: Quality Assurance for Canadian Grain and Market Support.

A) Quality Assurance work includes:

i) Technical and scientific support for the CGC's Grain Inspection Division.
   a) Development of rapid instrumental methods for analysis of such factors as grain hardness, protein content, oilseed chlorophyll, varietal I.D., etc.
   b) Research studies on the effect of different damage factors (frost, immaturity, sprouting, weathering, etc.) on end-use quality.
   c) Calibration and monitoring of instruments currently used for operational testing of grain moisture, protein, etc.

ii) Monitoring of carlots and cargoes of the different grades of the various classes of Canadian grains and oilseeds. There are two major aspects to this work:
   a) After-the-fact surveys of the average quality of Canadian grain exports.
   b) Screening and monitoring programs to ensure freedom from toxic residues (pesticide residues and mycotoxins).

iii) Special investigations. As required, the GRL is called on to investigate enquiries or problems related to the quality of Canadian grain.

iv) New variety evaluation. Quality evaluation of experimental lines and potential and new varieties of Canadian grains and oilseeds is carried out in collaboration with Canadian plant breeders.

v) Basic research is essential to understand:
   a) The chemistry of "quality" (as it relates to grain components such as proteins, enzymes, carbohydrates, etc.).
   b) The technology of end-use processing of grains and oilseeds (flour and semolina milling, barley malting, oilseed crushing, baking, etc.) and quality factors influencing performance of different grades and classes of grain in different markets.
   c) How "quality" may most meaningfully be measured. An end-product of this activity is development of new or improved methods for quality evaluation that will improve the new crop, cargo and other surveys and generally help to evaluate grain quality more meaningfully.

B) Market Support. Marketing agencies, notably the Canadian Wheat Board, look to the GRL to provide technical and scientific support both in marketing different grades of each new crop and in developing new markets for existing and newly-developed classes of grains. This type of work includes:

i) Surveys of the average quality of different grades of the various classes of Canadian grains and oilseeds harvested each growing season. Quality data are incorporated in new crop bulletins published every autumn.

ii) Travel to overseas markets by GRL scientists and technologists to determine milling, baking and other grain processing methodology used in those countries.

iii) Research at the GRL to simulate processing methods and determine suitability of different grades of different classes of Canadian grain for specific end products.

iv) Further travel to existing markets and potential market countries to oversee and discuss commercial-scale test milling of wheat of existing and newly-developed classes (e.g., Canada Prairie Spring).

v) Provision of expert information and advice on the end-use quality characteristics of different grades of Canadian grain.

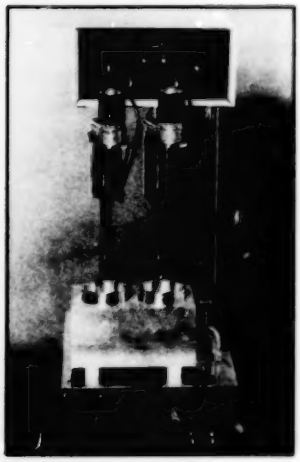
The introduction of new and expanded programs at the GRL has been accompanied by a steady increase in staff numbers, which have gone from 25 in 1945 to 39 in 1955, 61 in 1965, 80 in 1975 and over 100 today. It is predicted that while the work load of the Laboratory may well continue to increase, the rate of increase in personnel will level off as advantage is taken of new and improved methodology, much of which is automated and computer-assisted. It is anticipated, however, that Quality Assurance for Canadian Grain and Market Support will, in the foreseeable future, remain the two fundamental objectives for the research and related scientific activities at the GRL.

CURRENT STUDIES

COMMON WHEAT

Effect of Protein Content on the Quality of Canadian Hard Red Winter Wheat. Samples of Norstar wheat grown at several Saskatchewan locations under different levels of nitrogen fertilization (obtained from Dr. B. Fowler, University of Saskatchewan) were composited at five different protein content levels and subjected to quality evaluation tests — the results from which are being studied.

GRL Paste Viscosity Indicator. An instrument and method have been developed for measuring the paste viscosity of a heated slurry of ground grain and water. Resistance offered to a stirring device is reflected in a voltage signal representing the current requirements of a small d.c. motor. Paste viscosity decreases with increasing alpha-amylase levels in ground grain. A digital panel meter retains its reading at a fixed testing time of 3.5 minutes. The unit is portable (8.8 kg) and does not require a source of running water. Operation is straightforward and sample containers are low cost and disposable. Test results obtained using this method correlate well with those obtained using the Falling Number test for Canada Western Red Spring wheat samples analyzed to date.



The GRL Paste Viscosity Indicator.

Quality Characteristics of Some World Wheat Varieties. A collection of wheat varieties from several countries was obtained from the Canadian International Grains Institute. In collaboration with the Winnipeg Research Station of Agriculture Canada, the samples are currently undergoing milling, baking, analytical and physical dough tests. Osborne and neutral salt fractionations are being performed to determine the relationship between protein characteristics and quality parameters.

Quality of Canadian and American Cultivars of Semi-dwarf Wheat. In collaboration with Dr. L. Evans of the University of Manitoba and the Winnipeg Research Station, Agriculture Canada, six Canadian and 19 American semi-dwarf wheat cultivars were grown at seven locations in Manitoba and Saskatchewan. The quality characteristics of the cultivars are being determined.

Effects of Frost and Immaturity on Wheat Protein Properties. Osborne and neutral salt fractionation studies have been carried out on samples obtained previously from trials involving freezing wheat plants growing in the field. The data obtained from these tests are now being analyzed.

Wheat Cultivar Identification Using Sodium Dodecyl Sulphate Gradient Polyacrylamide Gel Electrophoresis (SDS Gradient PAGE). This technique was used to analyze the gliadin and high and low molecular weight glutenin subunits obtained from extracts of samples of 18 registered Canadian wheat cultivars and 9 non-registered wheat cultivars (8 American and 1 Canadian). All non-registered cultivars and their biotypes were distinguishable from registered cultivars. Eight different patterns of high molecular weight glutenin subunits were observed for the 27 cultivars and their biotypes - which aided in the discrimination procedure.

Wheat Cultivar Identification Using Reversed Phase-High Performance Liquid Chromatography (RP-HPLC). Evaluation of this procedure, which characterizes samples according to their gliadin and glutenin composition, has indicated that it is suitable for the identification of Canadian wheat cultivars. Although an analysis time of two hours provides optimum resolution of proteins, an analysis time as short as twenty minutes was sufficient to allow the majority of the 27 cultivars tested to be distinguished. Quantitative analysis of RP-HPLC chromatograms derived from testing admixtures of two cultivars (Neepawa and Len) indicated that the proportions of cultivars in the admixtures can be determined. The feasibility of RP-HPLC providing the mechanism for rapid cultivar identification without the need for single-kernel analysis is being studied.

Analyzing a chromatogram during wheat cultivar identification using reversed phase-high performance liquid chromatography.

DURUM WHEAT

The Role of Polar Lipids in Surface Stickiness of Cooked Spaghetti. Non-polar lipids have been found to affect the surface stickiness of cooked spaghetti; and the role of polar lipids is now being investigated. Reports in the literature indicate that polar lipids stabilize the helical structure of starch - thereby influencing surface characteristics. Starch isolated from defatted semolina was extracted with hot isopropanol or hot n-butanol to remove complexed polar lipids, and spaghetti was then processed from semolina reconstituted with the resulting starch. Results from quality tests performed on this spaghetti are being evaluated.

A Rapid Test for the Estimation of Spaghetti Cooking Quality. It has been shown that surface material that can be rinsed from the surface of cooked spaghetti is related to stickiness of cooked spaghetti. Since amylose is a principal component of the surface material, a method for measuring the intensity of the color of the amylose-iodine complex was developed for estimating the amount of amylose (and therefore the total material) rinsed from the surface of spaghetti. In a test of 33 samples of commercially-processed spaghetti, the correlation coefficient between surface stickiness (measured instrumentally) and amylose-iodine color value was 0.46 (significant at the 1% level). For the same samples, the correlation coefficient between cooking loss and amylose-iodine color was 0.78. In tests of laboratory-processed spaghetti samples, the corresponding correlation coefficients were 0.93 for stickiness versus color and 0.47 for cooking loss versus color.

Effect of Various Alkali Salts on Noodle Quality. A study has been initiated into the effects of various combinations of alkali salts (carbonates and phosphates of sodium and potassium) on noodle quality. Straight-grade flours milled from four classes of wheat have been processed with combinations of small concentrations of the salts. The tests performed on the resulting noodles include: wet noodle color, dried noodle breaking strength and protein fractionation of the dried noodles using the Osborne method.

An Improved Durum Wheat Semolina Milling Procedure for the Allis-Chalmers Laboratory Mill. An improved durum wheat semolina flow has been developed for a four-stand Allis-Chalmers mill. The drive mechanism and the seive construction of the GRL sifter normally used for common wheat milling were modified to make the sifter suitable for semolina milling. New sizing rolls were incorporated into one of the roll stands, and the clothing, throw and airflow of the Laboratory purifier were optimized to improve semolina quality. Typical semolina extraction rate is about 65% (72% including flour). The new Allis-Chalmers semolina milling procedure has a higher sample throughput than the Bühler laboratory mill and has been adopted as the standard milling procedure for both research and variety testing projects. Cargo and new crop composites will continue to be milled using the Bühler laboratory mill to permit continuity of published quality data.

A Durum Wheat Semolina Milling Procedure for the Grain Research Laboratory Pilot Mill. A procedure to produce about 65% extraction semolina (72% extraction including flour) from typical amber durum wheat has been developed. The flow consists of four breaks, three sizings and two reductions. The latter two passes are used to pick up residual low grade flour in order to get a better estimate of total extraction potential. Four purifier passes are used - two primary and two secondary. Once the purifiers are fully loaded, semolina can be taken directly from the mill without further cleanup. Semolina generated prior to full purifier loading and during mill clean down (about 2 kg) is repurified using the Laboratory purifier. The reproducibility of pilot-scale millings is comparable to that of laboratory-scale millings and the pilot mill system promises to be very useful for large millings for research or service testing purposes. Samples of up to 500 kg can be milled in one day - compared with laboratory-scale milling procedures that generally have a capacity of 10 to 15 kg per day.

Cleaning a roll stand in the GRL Pilot Mill.

Durum Wheat Hardness and Vitreousness Studies. Individual durum wheat carlot samples of good visual quality were segregated on the basis of starchy kernel content as determined at the Grain Inspection Division, Canadian Grain Commission, and on the basis of kernel hardness determined by near infrared reflectance spectroscopy. Composite samples were milled into semolina to allow the influence of vitreousness and hardness on milling performance to be determined. Results indicate that starchy kernels may not affect durum wheat milling performance as much as commonly believed. Although durum wheat kernel hardness tends to increase as vitreousness increases, fully starchy durum wheat kernels are still somewhat harder than vitreous hard red spring wheat. Durum wheat kernels that are partially or predominantly starchy are comparable in hardness to those that are fully vitreous. As a result the carlot samples exhibited a narrow range of hardness (PSI approximately 30 to 37) and little effect of vitreousness on semolina yield was apparent. Slight shifts in first break release, milling energy consumption and flour starch damage were observed between samples, consistent with hardness results.

The well-established relationship of durum wheat vitreousness to protein content was confirmed. Fully starchy kernels were about 3% lower in protein content than corresponding fully vitreous kernels, whereas partially starchy kernels exhibited intermediate protein content levels. Work is continuing on some pure cultivars to determine whether durum wheat protein composition is related to vitreousness.

BARLEY

Barley Cultivar Identification by Sodium Dodecyl Sulfate Gradient Polyacrylamide Gel Electrophoresis (SDS Gradient PAGE). The SDS gradient PAGE technique was evaluated to determine whether it could provide improved resolution of hordein proteins concomitant with improved discrimination (identification) of Canadian barley cultivars. Electrophoretic analysis of 100 barley cultivars revealed that, in general, superior resolution was achieved with SDS gradient PAGE than with acidic PAGE but considerable duplication of protein patterns among cultivars and their biotypes remained a problem. A cultivar catalogue of protein patterns was prepared, and the technique has been used successfully to identify barley samples for the Grain Inspection Division of the Canadian Grain Commission, plant breeders and producers.

Papain as an Extractant of Bound Beta-amylase from Barley. Crude papain (Sigma, Type II) has two distinctive types of activity toward barley: "reducing" and "enzymic". The substrate used to detect these activities was "barley spent grains" from which the readily soluble "free" beta-amylase was removed, leaving primarily "bound" beta-amylase associated with freeze-dried "spent grains". The two sources of activity were separated by ion-exchange chromatography

on carboxymethyl (CM) cellulose. Following incubation of each of these fractions with "barley spent grains", it was demonstrated by isoelectric focusing that the "reducing" fraction released "barley-type" beta-amylase enzymes while the "enzymic" fraction released "malt-type" beta-amylases. The "reducing" fraction from crude papain was heat-stable, had relatively low molecular weight and was rich in sulfhydryl content. The "reducing" fraction is a mixture of three amino acids and at least nine peptides which are currently being separated and purified further. The "enzymic" fraction of crude papain was heat-stable and had a relatively high molecular weight. This fraction is rich in proteolytic activity. Analysis of purified papain (Sigma, 2 x crystallized) revealed two proteolytic fractions and no "reducing" activity when purified further on CM-cellulose. Only the second proteolytic fraction produced "malt-type" beta-amylase when incubated with "barley spent grains".

Alpha-amylase Components in Germinated Kernels of a Number of Different Cereals. Qualitative analysis, using isoelectric focusing, showed that germinated samples of barley, wheat, rye and triticale contained two major groups of alpha-amylase. These have been designated low and high pI groups. Both groups were heterogeneous but the high pI group had a more complex alpha-amylase pattern than did the low pI group. In addition, different patterns were obtained for each cereal.

The quantitative technique of chromatofocusing was used to determine relative proportions of the two major alpha-amylase groups in the different cereals. Although the high pI group predominated, its proportion of the total alpha-amylase activity varied from a high of 98% for barley to a low of 80% for durum wheat.

Similar analyses were performed on germinated samples of millet, corn, oats, sorghum and rice. These grains did not contain high pI alpha-amylase components; only a heterogeneous low pI group was detected. The major components appeared to have lower pI values than the low pI components of barley, wheat, rye and triticale.

Extracts of all germinated grains were treated with antibodies raised against low pI alpha-amylase from germinated barley, prior to isoelectric focusing. As expected, all low pI components from barley, wheat, rye and triticale were removed by the antibodies. Alpha-amylase components of rice and oats were not affected but the lowest pI components of sorghum, millet and corn appeared to react with the antibodies. These results suggest there are alpha-amylase components in sorghum, millet and corn that share at least partial immunochemical identity with the low pI components of barley, wheat, rye and triticale. In general, however, the low pI alpha-amylases of these grains are quite distinct from those of the other grains studied.

Determination of Alpha-amylase Activity in Barley Malt. Rates of amylose hydrolysis by alpha-amylases 1 and 2 from barley malt were determined by end-group analysis. Using this technique, alpha-amylase activity in terms of substrate bonds broken/min/enzyme molecule can now be calculated. The specific activity of alpha-amylase 2 (the high pI component) appeared to be twice as high as that of alpha-amylase 1. Equal activities of the two enzymes, based on hydrolysis of amylose, have similar rates of hydrolysis on amylopectin beta-limit dextrin. This confirms that beta-limit dextrin, a widely-used substrate for alpha-amylase assays, is equally susceptible to hydrolysis by the major alpha-amylase components of barley malt.

OILSEEDS

Starch Degrading Enzymes in Canola Seeds (with Dr. L. Van Waeseele, Department of Botany, University of Manitoba). Epidermal cells of immature canola seeds contain small, transitory granules of starch. These may be the energy source for formation of the mucilage found on the outside of canola seeds. An investigation has been started on the enzymes responsible for degradation of this starch. Preliminary results suggest that there is an alpha-amylase present in immature seeds that decreases in activity as the seeds mature. This enzyme may be similar to the alpha-amylase present in immature pericarp tissues of barley and wheat and is believed to be responsible for hydrolysis of transitory starch granules found in these tissues.

Measurement of Chlorophyll Content in Canola Seeds. Analysis of chlorophyll pigments extracted from samples of canola seeds of varying degrees of immaturity showed that both chlorophyll *a* and chlorophyll *b* were present in an unchanging ratio of about three moles chlorophyll *a* to one mole chlorophyll *b*. Comparison of total chlorophyll content estimated by both the extraction-spectrophotometric procedure and the high performance liquid chromatography (HPLC) procedure suggested that the extraction procedure (based on spectrophotometric measurements at 667 nm) was detecting only the chlorophyll *a* present. Wavelength maxima in the red region for chlorophyll pigments are: chlorophyll *a* - about 665 nm, chlorophyll *b* - about 645 nm.

Measurement of Chlorophyll Content in Canola Oil. The HPLC determination of chlorophyll pigments in crude and degummed canola oils has confirmed that pheophytins are the predominant forms of chlorophyll present in oils after commercial extraction. The American Oil Chemists' Society (AOCS) Procedure Cc 13d-55 (1981) for chlorophyll determinations in oils was compared with a revised

spectrophotometric determination based on calibration with pheophytin *a*. The revised procedure gave results 1.4 times higher than the AOCS procedure. The HPLC procedure accounted for 80% of the pigments determined by the revised procedure. Further examination of chlorophyll-related pigments in crude and degummed canola oil is planned in order to fully elucidate the contribution of chlorophyll pigments to overall oil color.

Relationship Between Chlorophyll Content and Green Seeds. Canola and rapeseed are graded for green color based on the assessment of distinctly green seeds and background color; but the poor correlation (r = ca. 0.7) between green seeds and chlorophyll content has been a source of concern for some time. The use of NIR technology to determine chlorophyll content in canola seed has now made possible the analysis of large numbers of samples in a reasonable length of time for both green seeds (%) and chlorophyll content (ppm). For the 1986 harvest survey of canola, 904 samples were analyzed for chlorophyll content, grade, and % green seeds.

Twenty-four percent (24%) of the No. 1 Canada samples exhibited a chlorophyll content greater than 22 ppm - a value which was selected, based on crushing industry requirements, as being a reasonable maximum concentration for top grade seed. Fifty-seven percent (57%) of the No. 2 Canada grade samples exhibited a concentration greater than this limit. In addition, chlorophyll content was found to increase by 2 to 3 ppm for each percentage unit increase in green seeds and the range in chlorophyll content at any given percentage value of green seeds averaged 19 ppm. The *Brassica napus* canola varieties (Westar and Triton) were found to have higher chlorophyll background levels than the *Brassica campestris* variety (Tobin), and all varieties tested exhibited the same green seed-to-chlorophyll relationship.

Determination of Glucosinolate Content in Canola. The thymol procedure originally drafted in December of 1985 has been modified and the improvements achieved include: more efficient elution of strongly-bound glucosinolates; direct spectrophotometric measurement of the thymol complex in capped tubes; and elimination of the oil-removal step prior to extraction of the glucosinolates. In a collaborative study with CETIOM (Centre Technique Interprofessionnel des Oléagineux Métropolitains) it was demonstrated that removal of oil before gas-liquid chromatography analysis, the proposed method of the International Standards Organization (ISO), was not necessary. In addition, reducing the desulphoglucosinolate aliquot size from 1600 to 200 microlitres resulted in a considerable saving of expensive derivatization reagents without loss of accuracy or precision.

Constituents of Crude and Degummed Canola Oils. Two spectrophotometric procedures for the determination of iron content in canola oil were evaluated and because similar results were obtained using both techniques, the simpler one was selected and used to determine the level of iron in samples of oil from Canadian crushing plants. Iron content varied with plant location - with a mean of 5 ppm and range of 2 to 10 ppm. In general, solvent-extracted oil contained more iron than pressed oil.

In phosphorus analysis studies of these samples, the phosphorus content averaged 300 ppm in crude oil (with a range of 100 to 800 ppm) and averaged about 50 ppm in degummed oil (with a range of 2 to 200 ppm). Work is continuing on the quantification of the various phospholipids present in oil.

Quality of Damaged Soybeans. The extremely wet weather experienced in the soybean growing region of Ontario resulted in many samples of soybeans being degraded because of the presence of pink and black colored beans. A composite sample of No. 4 Canada soybeans was examined and found to contain clean (20.6%), light black (44.9%), dark black (21.4%), and red (13.1%) portions. *Fusarium sporotrichioides*, a producer of vomitoxin and HT-2 toxin, was found on the light black (14%), dark black (30%) and red (22%) colored seeds. Analysis of the red and black beans showed the presence of significant levels of these toxins in the meat portion of the seed.

There was no significant difference in oil content, protein content, fatty acid composition and oil color between clean and colored beans - although lower oil content values were evident in the red seeds and dehulled seeds exhibited lower fat acidity values. Significant differences were noted between the colors of the meals.

Analysis of seed, oil and meal samples obtained from two different crushing plants revealed only traces of vomitoxin and HT-2 toxin in the meal from No. 3 Canada grade seed and no toxins present in the meal from No. 1 Canada grade seed or in the oil from seed of both these grades.

Determination of Oil Content Using the AOCS and ISO Methods. Studies performed in previous years had indicated that AOCS Method Ai3-75 (1980) gave similar results to the longer ISO 659 regrind procedure. A re-examination of this procedure using "Swedish Tubes" as the optional mechanical grinder was prompted by low results obtained in a check sample program. Although the AOCS procedure gave results comparable to the ISO method for sunflowerseed, lower values were obtained for canola, rapeseed and flaxseed. The ISO procedure has been adopted as the official Canadian Grain Commission procedure and results from previous surveys have been adjusted to reflect the slightly higher (ca. 1%) oil content values.

RESIDUE ANALYSIS

Pesticide Residue Analysis Methodology. Use of capillary column gas chromatography with mass selective detection (MSD) is being investigated for multi-residue pesticide screening of cereal grain samples. Initial studies involved simultaneous screening of over 50 pesticides in a single chromatographic run with selected ion monitoring for two characteristic ions per compound. Further studies are ongoing for evaluating the MSD approach as an alternative to pesticide residue screening using electron capture, nitrogen-phosphorus and flame photometric detectors.

Methods Development for Determining Mycotoxins in Grains. Attention has been focused upon improving the Research Laboratory's method for determining *Fusarium* trichothecene mycotoxins in wheat and corn. This method makes use of capillary column gas chromatography with mass selective detection (CG-MSD). Initially, this method was devised for determination of vomitoxin, but subsequently the scope has been increased to include diacetoxyscirpenol, HT-2 toxin and T-2 toxin. Preliminary studies have also been initiated to include nivalenol testing. The rapidity of this method has been increased by using a single cleanup step involving Sephadex LH-20. In order to take full advantage of gel permeation chromatography (GPC) cleanup, an automated GPC system has been purchased for incorporation into this method. Other methods being investigated include thin layer chromatography procedures for determination of ochratoxin *A* and zearalenone in wheat, barley and corn.

Screening of Wheat, Barley and Corn Cargo Shipments for Mycotoxins. The Research Laboratory's screening program for the presence of mycotoxins in cargo shipments of Canadian grain was expanded considerably for the 1985-86 crop year. A total of 74 analyses for *fusarium* trichothecene mycotoxins were carried out on selected grades of five classes of western Canadian wheat. Vomitoxin was not detected at an amount above 0.05 ppm in any sample of soft white spring wheat, No. 3 Canada Western Red Spring wheat or No. 3 Canada Western Amber Durum wheat, but was detected in 73% of the Canada Prairie Spring wheat samples and in 20% of the Canada Feed wheat samples. The levels were generally very low - with 0.15 ppm being the highest concentration found. Testing for the presence of ochratoxin *A* was also performed on 33 samples of Canada Feed wheat. In no case was ochratoxin *A* detected above the detection limit of the analytical method, 0.05 ppm.

A total of 75 cargo shipments of Ontario-grown Canada Eastern White Winter wheat were screened for *fusarium* trichothecene mycotoxins during the 1985-86 crop year. Most samples were positive for vomitoxin at a level above 0.05 ppm. The level exceeded 0.50 ppm in 19% of the samples and the highest concentration recorded was 1.5 ppm.

Corn shipments made during the 1985-86 crop year were screened for trichothecenes, ochratoxin *A* and aflatoxins. While all samples were found to have levels of vomitoxin above 0.5 ppm, ochratoxin *A* and aflatoxins were not detected. The amount of vomitoxin present was above 2.0 ppm in 58% of the samples with the highest level recorded being 5.7 ppm. Twenty-four cargo samples of western Canadian barley were screened for the presence of ochratoxin *A* and aflatoxins and six samples were tested for trichothecenes. All results for these tests were negative.

Relationship of Vomitoxin Levels to the Presence of "Tombstone" Kernels in Wheat. Visually, the main distinguishing feature of wheat affected by *fusarium* head blight is the presence of "tombstone" kernels in the sample. This condition is characterized by kernels which are typically thin, pale and shrunken and which may show evidence of a white mould. The relationship between the levels of vomitoxin and "tombstone" kernels in wheat is of interest for the purpose of predicting the level of vomitoxin in wheat containing "tombstone" kernels. Data are currently being collected for the purpose of improving estimation of the functional relationship between levels of vomitoxin and "tombstone" in amber durum and eastern white winter wheat. Initial indications are that at "tombstone" levels of 0.5 and 1.0%, the concentration of vomitoxin in the sample is not likely to exceed 1.0 and 2.0 ppm.

***Fusarium* Trichothecene Mycotoxins in 1986 Ontario White Winter Wheat.** Following detection of higher than normal levels of "tombstone" wheat in early deliveries, the Canadian Grain Commission carried out a special investigation of vomitoxin levels in the 1986 Ontario white winter wheat crop. A total of 93 terminal elevator composites of daily deliveries made over the period mid-July to early August were tested for the major *fusarium* toxins.

Screening for *Fusarium* Trichothecene Toxins in 1986 Manitoba Wheat. In 1986, *fusarium* head blight was once again detected in wheat fields in the Red River valley area of southern Manitoba. In order to eliminate any potential hazards associated with new-crop wheat, samples found to contain affected kernels were screened for the presence of four *fusarium* trichothecene mycotoxins - vomitoxin (DON), diacetoxyscirpenol (DAS), HT-2 toxin and T-2 toxin. A total of 117 samples were tested from 73 stations in Manitoba.

Pesticide Residue Monitoring of Export Cargoes of Wheat, Barley, Oats, Rye and Rapeseed. Canadian exports of wheat, barley, oats, rye and rapeseed are screened for residues of common organochlorine, organophosphate and organonitrogen pesticide chemicals. This is part of a continuing program to ensure that cargoes of Canadian grain are free from toxic residues and meet both Canadian and international tolerances. In the 1985-86 crop year, analyses were carried out on 1,254 cargoes. In addition, 176 samples were tested for the presence of ethylene dibromide (EDB), and in no case was EDB detected above the detection limit of the analytical method, 0.005 ppm.

OTHER TOPICS

Grain Biology Studies and Services. A project to organize, describe and catalogue a growing collection of over 2000 color slides of grain has been completed. A computerized data storage and retrieval system has been implemented for quick access to any slide. Slides are catalogued by grain kind, major factor, descriptive key words, and cross-referenced with appropriate research or test data.

A new program was launched to document cases of stained kernels suspect for poisonous seed treatments. Kernels, from samples intercepted at terminal elevator inspection points, are photographed with identification numbers prior to chemical analysis in the Residue Analysis section. Chemical analysis destroys the suspect kernels and the photograph is retained as evidence.

Illustrations for a Red Spring Wheat Grading Factors Manual are being selected and organized, and preparations for the accompanying text are underway.

Mycology Studies. An examination of eastern and western Canadian wheat exhibiting *fusarium* head blight has revealed that while the primary agent of the disease in wheat from both regions is *F. graminearum*, the next most frequent cause in eastern wheat is *F. poae* and in western wheat is *F. sporotrichioides*. It is important to note this difference because mycotoxin residue analysis revealed that only DON was detected in the eastern samples but that both DON and HT-2 toxin were detected in the western samples. Results from this monitoring program also suggest that durum and semi-dwarf wheats are more susceptible to infection than red spring wheat.

In 1986, some Ontario grown barley exhibited *F. graminearum* infection - as did some soybean, which is not normally a host for this microorganism. Consequently, soybean exports are now being monitored for the presence of molds and mycotoxins.

An examination of the effect of artificial drying on the mycoflora of corn revealed a substantial decline in some species, with members of the *Mucorales* and *Fusaria* (notably *F. graminearum*) being most seriously affected. Therefore, mycological analysis of dried corn for *Fusaria* may result in grossly underestimated levels for the undried corn.

In a collaborative project with Drs. Sinha and Abramson of the Winnipeg Research Station, Agriculture Canada, the vulnerability of Canadian red spring and HY320 wheat and barley to fungal infection and mycotoxin production is being examined. In results to date, a species of *Aspergillus* previously believed to be rare in these hosts has been isolated quite frequently.

VARIETY STUDIES

An important function of the Research Laboratory is the end-use quality evaluation of new cultivars of the different classes of wheat, malting barley and oilseeds. These cultivars are tested by the plant breeders for disease resistance and agronomic potential and by cereal technologists for "end-use" quality. The Laboratory is a major participant in this quality evaluation program. Results are presented at the annual meeting of the Expert Committees under the auspices of the Canada Agriculture Services Co-ordinating Committee. Disposition of new cultivars is based on data provided by the disease, breeding and quality subcommittees. Only those new cultivars that measure up to certain minimum standards of "end-use" quality, disease resistance and overall agronomic performance are considered for registration for eventual commercial production.

BARLEY CULTIVARS

Harrington was licensed in 1981 as a possible replacement for Klages in the traditional two-rowed barley area of the western Prairies. It underwent extensive commercial carlot testing following the 1982 and 1983 crop years and has since been purchased extensively by domestic brewers. The barley area seeded to Harrington increased from 8% in 1985 to 18.4% in 1986 while the area seeded to Klages declined from 22.5% to 18.3%. Compared to Klages, Harrington matures earlier, is higher yielding and produces a much higher percentage of plump kernels. It seems likely that Harrington will become the major two-rowed cultivar grown on the western Prairies for domestic brewing.

Ellice, although approved for licensing in 1983, was not registered until December 1986, and in the interim period has undergone extensive commercial testing. It was developed primarily for the eastern Prairies where two-rowed malting cultivars have never performed satisfactorily. Ellice is resistant to stem rust, is tolerant or resistant to most leaf-borne diseases and, compared with other two-rowed malting cultivars, has several unique characteristics. It steeps and modifies more quickly and produces worts with very low amounts of beta-glucans but with somewhat elevated levels of wort-soluble nitrogen. Low malt peroxidase activity is also exhibited.

Thirteen carlots of Ellice grown during the 1986 crop year were purchased for the final stages of commercial testing during 1987. Based on results of malting and brewing trials conducted on carlots from the 1984 and 1985 crops, domestic maltsters and brewers have indicated that Ellice should be an acceptable two-rowed malting cultivar.

NEAR-INFRARED REFLECTANCE SPECTROSCOPY AT THE CANADIAN GRAIN COMMISSION

Introduction

Near-infrared reflectance (NIR) spectroscopy is a relatively recent addition to the analytical tools available to the grain and food technologist. It is a simple, rapid procedure requiring only about one minute per test - with no weighing of sample necessary. Accuracy and precision (reproducibility) are adequate for most industrial needs (1) and in addition to being suitable for use in laboratories, modern NIR instruments are compact and robust enough for use in grain elevators and other areas where rapid throughput is necessary in dusty and uncontrolled environmental conditions. Near-infrared reflectance analysis depends on spectroscopic identification of molecules of individual constituents among the total number of molecules present in the sample viewed by the instrument. The information used in analysis arises from diffuse reflectance of light energy at wavelengths specific to the constituents to be determined. Calibration of the instruments using samples of known composition enables the technique to be made quantitative.

At present, the Grain Research Laboratory (GRL) possesses a Cary Model 17I computerized visible/NIR scanning spectrophotometer and a Pacific Scientific Model 6250 Research Composition Analyzer (comprising a computerized monochromator scanning the wavelength range from 600 to 2500 nanometers (nm) and a Model 7000 "Compscan" fully-computerized seven-filter analyzer scanning from 1350 to 2400 nm). The GRL also has two simpler bench-type instruments: a Pacific Scientific Feed Quality Analyzer Model 51A and a DICKEY-john GAC III. This comprehensive set of NIR instruments enables the GRL to research a wide range of possible applications and translate the research findings into operational uses incorporating the simpler type of instruments located in flour and feed mills and grain elevator company offices.

Theory

Spectroscopic measurements in the near-infrared differ from those in the classical mid-infrared in that practically all of the usable signals come from overtones or combinations of overtones of fundamental absorbances that arise in the mid-infrared region from 3500 to about 2500 nm. The signals in the near-infrared are very much weaker than those in the mid-infrared, but the detectors used in near-infrared region work are commensurately more sensitive and the irradiation sources can be more intense than those used in the mid-infrared instruments. Because of the existence in the near-infrared region of first, second, third and higher overtones and overtone combinations, many bands overlap and the spectra tend to be relatively featureless (Figure 1). Consequently, the instruments require a built-in computer to resolve the bands into discrete signals. Derivatization of the signals before computation may assist in the resolution, and simplifies the interpretation of spectra for the chemist. Figure 2 illustrates the second derivative spectrum of wheat gluten superimposed on the original log 1/R spectrum (R = reflectance energy value). Whereas only 17 bands and shoulders can be discerned in the log 1/R spectrum, the second derivative of optical density (D2OD) spectrum shows 42.

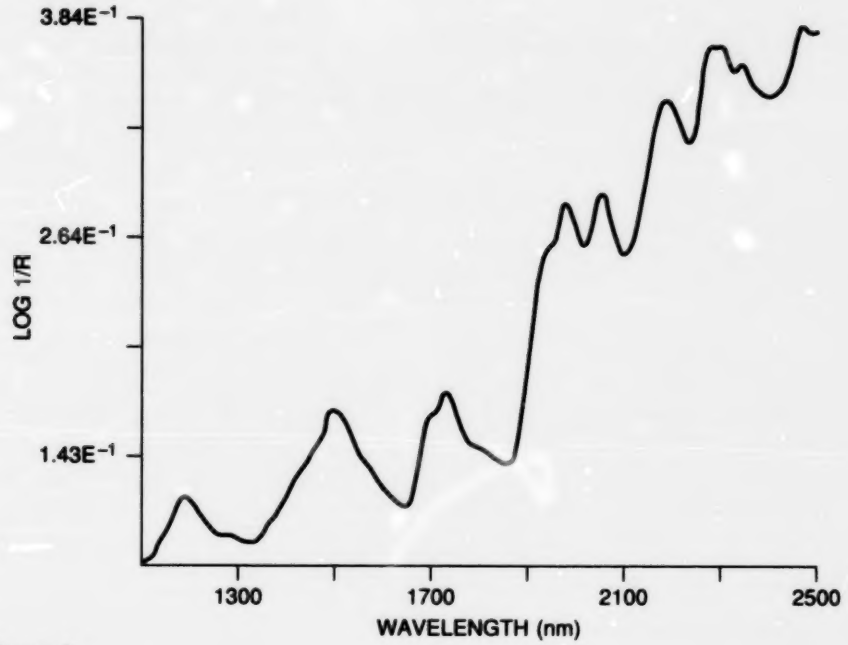


Figure 1
Near-infrared diffuse reflectance spectrum of wheat gluten (protein content = 95%, dry matter basis).

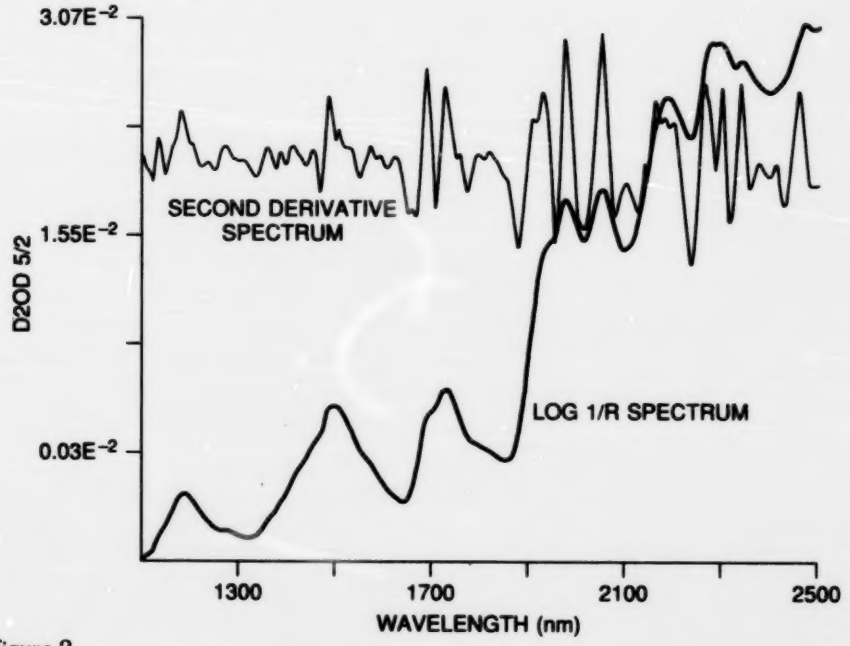


Figure 2
Near-infrared diffuse reflectance spectra of wheat gluten (protein content = 95%, dry matter basis). For the second derivative (D20D) spectrum, segment size was 5 wavelength points (about 10 nm) and derivative or "gap" size was two wavelength points.

Near-infrared spectrophotometers may measure light energy reflected from a sample surface (reflectance), or light which passes through the sample (transmittance). The instruments are equipped with a white light source (usually a tungsten/halogen lamp), a system of focussing and wavelength selection, a reflectance standard and sample presentation system, detectors, an encoding/decoding system (to inform the computer which wavelength or filter is to be processed), amplification circuitry, an analog or digital microprocessor for data manipulation, and a digital display. The layout is illustrated in Figure 3. Modern instruments all use digital microprocessors. The wavelength selection system may take the form of discrete filters, which have a half-height bandpass of about ± 5 nm about a central or primary wavelength, a monochromator which is usually set to scan between 1000 and 2500 nm, or a tilting filter system. When an optical filter is tilted from the horizontal, its primary wavelength shifts downward from the primary point and the filter "scans" a wavelength range equivalent to about 9% of the primary wavelength (Figure 4). This wavelength region is available for use, so that an instrument with six tilting filters can utilize a very large wavelength range. For example, a filter with primary wavelength of 2192 nm can be used down to approximately 2000 nm. A computerized encoder is used in conjunction with tilting filters to direct the system to take readings at specific wavelength points. The most recent innovation to wavelength generation has been the introduction of NIR light-emitting diodes which emit light over narrow wavelength ranges. At present, these are available only at fairly small wavelengths, and are used in conjunction with narrow band-pass filters in near-infrared transmittance instruments such as the Trebor GT-90.

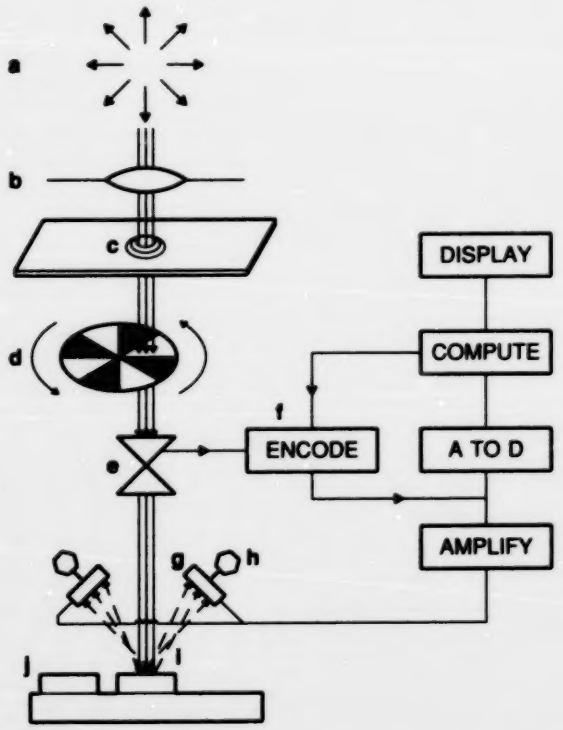


Figure 3
Basic NIR analytical system: a = light source; b = collimating lens; c = slit system; d = chopper wheel (optional); e = NIR interference filter system; f = encoder; g = detector; h = detector cooling system (optional); i = sample cell; j = diffuse reflectance standard.

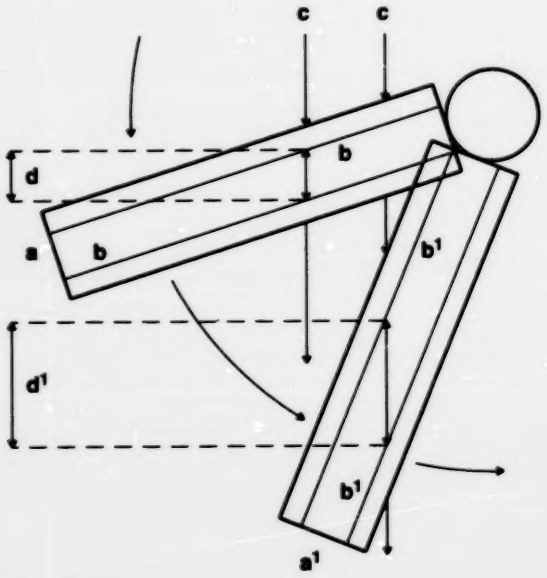


Figure 4
Tilting filter principle: a,a¹ = interference filter in two positions; b,b¹ = internal mirrored surface of glass layers; c = incident light; d,d¹ = effective distance between mirrored surfaces - it is this distance which controls the wavelength of an interference filter.

"White light" can be split into the familiar primary colours of the visible spectrum by means of a prism. The wavelength range of visible light stretches from about 300 to 700 nm, but white light contains light energy wavelengths from less than 100 to more than 50,000 nm. The region used by most NIR instruments extends from about 1400 to 2400 nm. NIR instruments convert light energy into electronic impulses by means of their detectors. These minute electronic signals are amplified and stored in two sets of capacitors, one set for signals received from the internal standard (usually ceramic or sand-blasted gold), the other for signals received from the sample.

The internal standard serves as a baseline. The instrument subtracts the signal from the standard from that received from the sample and computes the result into values for protein, moisture and other constituents. To do this, the instruments must be calibrated, using samples of known composition which have been analyzed by a reference chemical or physicochemical method of analysis. Calibration, for example for the determination of protein content in wheat, involves identifying the chief sources of variance such as grade, growing location, season, protein content and moisture content, and assembling a set of at least 50 but preferably 100 or more samples representing all of these sources of variance. Samples bearing the constituents to be determined should be distributed as uniformly as possible across the anticipated range in concentration. The samples are cleaned, ground in a Cyclone grinder (or equivalent) and introduced into the instrument. The optical data from the instrument are recorded for each sample. The chemical or physicochemical parameters for which the instrument is to be calibrated are determined by a reference method such as the Kjeldahl method for protein content, and the calibration constants computed using multiple regression analysis. The constants are set into the instrument, and the accuracy of the calibration verified by analyzing 12-20 samples of known composition, which have not been used in the calibration. A slope/bias adjustment is then carried out, if necessary, to "fine-tune" the calibration.

History

Near-infrared spectroscopy was originally developed at the Instrumentation Research Laboratory, United States Department of Agriculture, Beltsville, Maryland, under the direction of K. H. Norris (2). The pioneer work was carried out in transmittance mode, using carbon tetrachloride mulls (thick slurries). The Beltsville laboratory began studies on near-infrared reflectance around 1970. The Grain Research Laboratory (GRL) has been very active in the field of NIR technology since 1972 and played an important role in resolving technical difficulties in the earlier instrumentation.

The first commercially-available bench-top instruments were the Neotec Grain Quality Analyzer (GQA) (Figure 5), and the DICKEY-john Grain Analysis Computer (GAC) (Figure 6). Both were introduced during 1971 at the Illinois State Fair. NIR technology was introduced to Canada by the Grain Research Laboratory in February, 1972. The instrument was a Grain Quality Analyzer (GQA) Model I, manufactured by Neotec Corporation, then of Rockville, MD. The GQA was purchased with the objective of developing a rapid, practicable method of testing carlots and cargoes of hard red spring wheat for protein and moisture content at terminal grain elevators, where the top two grades of Canada Western Red Spring wheat is segregated into several guaranteed protein content levels. The GQA I employed tilting filter optics with

Figure 5
Neotec Grain Quality Analyzer (GQA) Model 1.

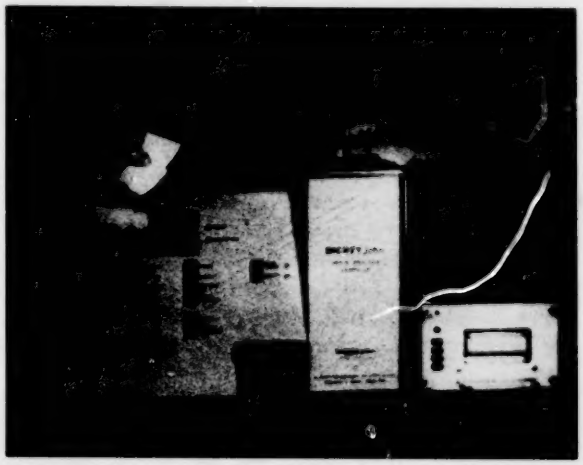


Figure 6
DICKEY-john Grain Analysis Computer (GAC) Model 1.

three filters, an encoder, four lead sulphide detectors, amplification circuitry, and an analog computer. The early work at the GRL involved evaluation of the accuracy and precision of the determination of protein and moisture content in wheat by comparison with the standard Kjeldahl and forced draught air oven techniques. At the same time, several sources of error in the technique and instrumentation were identified, and methods sought for their correction.

The original GQA I was found to be sensitive to ambient temperature. Deviations in GQA protein and moisture values from Kjeldahl and forced-air oven results were, respectively, negatively and positively correlated with ambient temperature (3). The manufacturer corrected this by thermoelectric cooling of the lead sulphide detectors. The modified GQA I was subject to frequent breakdowns which usually necessitated re-calibration. The development of automated NIR equipment called the Automated Digital Analyzer (ADA) (Figures 7 to 9) led to the correction of this shortcoming. The ADA (4) was the first NIR instrument to employ digital computing. The consistently good performance of the ADA over the first six months of its existence indicated that the main flaw in the GQA I was likely associated with its analog circuitry. This problem was eventually traced by the manufacturer to a single component; and replacement of this component resulted in a significant improvement in durability.

Figure 7
The ADA. Sample preparation (grinding) area. Operators grind 78 samples in 20 minutes using the Udy Cyclone grinder.

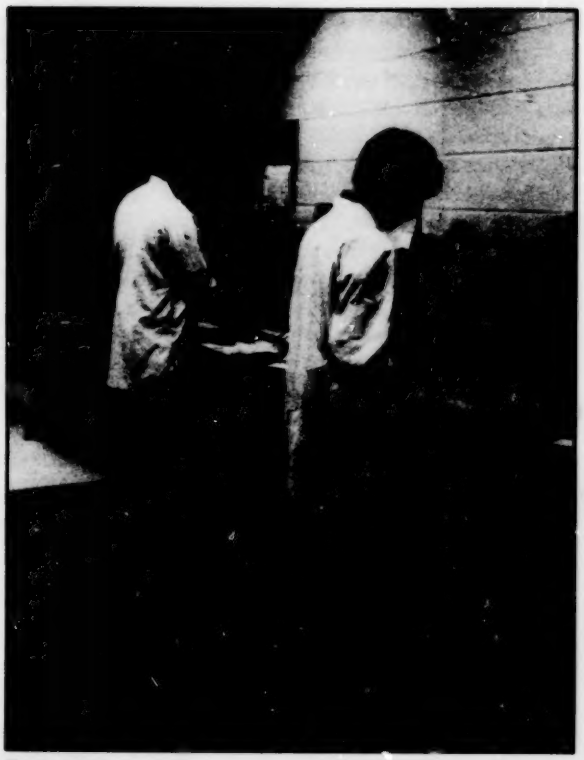


Figure 8
The ADA. Sample cell loading. Each sample tray holds 10 samples.

Figure 9
The ADA. Overall lay-out. A = sample access; B = sample egress; C = Nova 1220 computer; D = visual display.

Early Developments

Original NIR instruments all employed Teflon as a diffuse reflectance standard. Research at the GRL showed that these Teflon plates were highly susceptible to build-up of static electricity. A study at four terminal elevators in Vancouver, using a sealed "permacell" revealed a high degree of variability in readings taken between and within days on all four instruments. This was again corrected by the manufacturer, who replaced the Teflon standard with a ceramic plate. Subsequent research at the Grain Research Laboratory revealed that compressed resublimed sulphur is also an excellent diffuse reflectance standard for NIR instruments (5,6).

The chief factors affecting the performance of NIR instruments were identified as: variations in mean particle size and particle size distribution in the ground sample (7,8), variations in moisture content (9) and sample temperature (10), growing location and season (11), wheat variety (12), the number and source of samples used in calibration (13) and interactions between chemical constituents such as fibre, oil and moisture which affect particle size, shape and bulk density (14). The influences of mean particle size and moisture content on the NIR spectra of ground wheat are illustrated in Figures 10 and 11. Grinding by high speed impeller mill (the Udy Cyclone grinder) followed by thorough mixing of the ground sample will resolve the particle size factor, provided grinders are carefully maintained.

In a 1977 joint project with the USDA Instrument Research Laboratory, Beltsville, MD, studies aimed at minimizing the influences of both particle size and moisture content on the efficiency of NIR analysis of Canada Western Red Spring wheat for protein and moisture content resulted in the development of "quotient" mathematical treatment of NIR optical signals (7,9). This permitted the accurate NIR analysis of wheat with wide ranges in both particle size and moisture content, using calibrations based on samples having much smaller ranges in the values of these parameters. Near-infrared reflectance instruments have been calibrated for the determination of protein content using as few as two composite samples (representing high and low protein content) and accurate results were obtained over a three-year period without any adjustment of the constants (11). An earlier study in Canada based on large numbers of calibrations using two different types of instrument (15) had led to the development of universal constants, whereby results from samples representing all recognized sources of variance could be combined to yield a single set of calibration constants. This concept was tested at the same time as the two-point calibration (11) and is utilized by all NIR instrument manufacturers. Surveys, using NIR spectroscopy, of the protein content of the new-season crops of all types of Canadian wheat and barley have been carried out for several years. The raw log 1/R data are recorded and used to update universal calibration constants for use in the NIR instruments in terminal elevators.

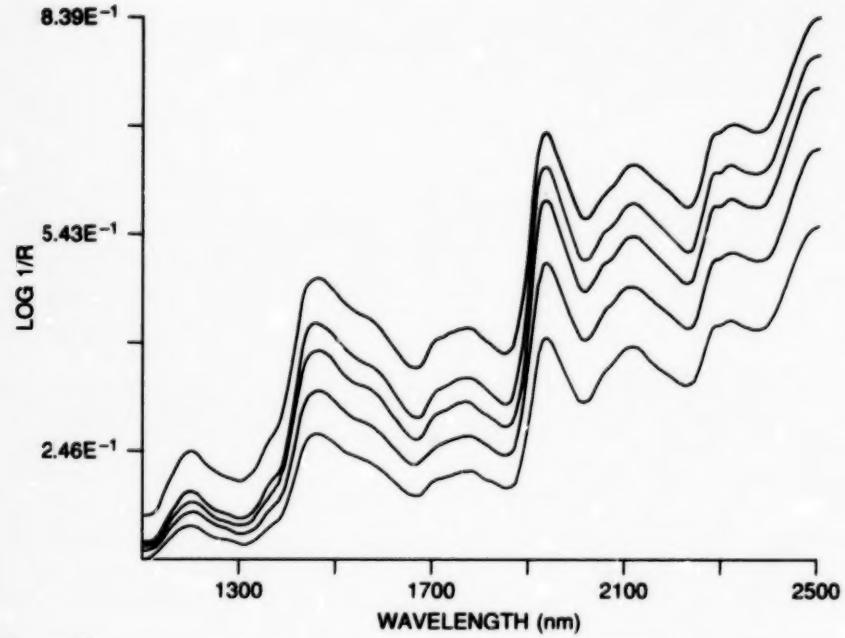


Figure 10
Influence of particle size on log 1/R spectra of ground wheat. The coarsest ground material exhibits the lowest reflectance.

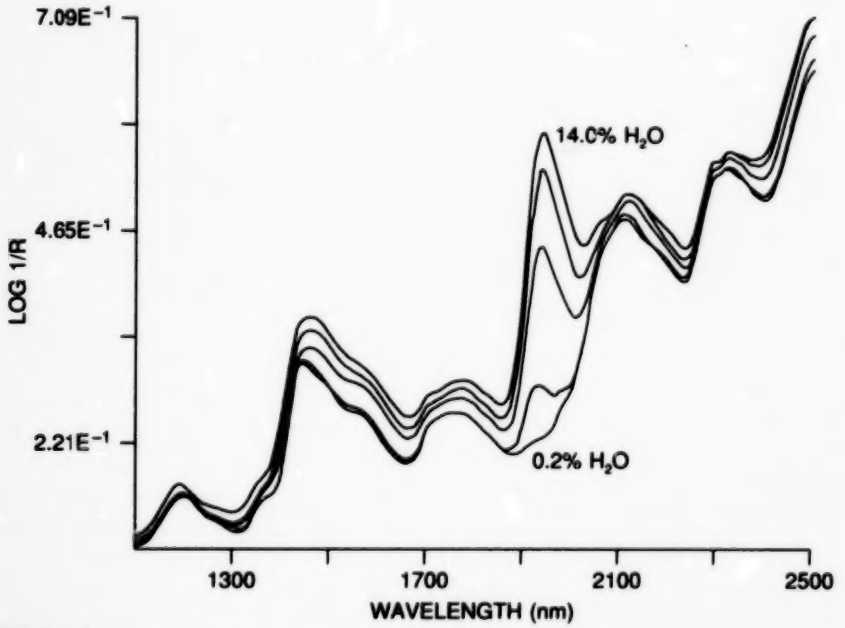


Figure 11
Influence of moisture content on log 1/R spectra of ground wheat. Note the significant differences in signal in the 1930-1940 nm region.

Because of their speed of operation, satisfactory accuracy and favorable economics (16), NIR instruments are currently being used in government and elevator company operations in western Canada to test most of the wheat and barley samples for protein content. The DICKEY-john GAC III (Figure 12) is used at Vancouver and the Trebor GT-90 whole grain analyzer (Figure 13) is used at Thunder Bay. Establishment of the NIR procedure at terminal grain elevators necessitated the installation of pneumatic systems for the rapid transfer of railway carlot unload samples and vessel loading samples, and the development of sound suppression cabinets for the Cyclone grinders. These modifications improved both the safety and efficiency of the sampling process. For the segregation of wheat at guaranteed protein content levels, a protein content determination must be completed within two minutes of the broaching of the railcar. The wheat is binned on the basis of the result of this test, and the protein content is verified by re-testing of the official unloading sample of the car by a NIR test in Winnipeg. The results of the latter NIR tests are used to monitor the accuracy of segregation, and also to establish guidelines or "bands" (ranges of protein content values) used for segregating wheat at the terminals during the following week of operation (Table 1). At times when the protein content is changing fairly rapidly (for example when the new season crop begins to enter the system) bands may be changed more frequently than once a week. The Canadian Grain Commission has carried out 400,000-600,000 protein content tests annually since 1972, the first year of segregation based on protein content.

Figure 12
The DICKEY-john GAC Model III.

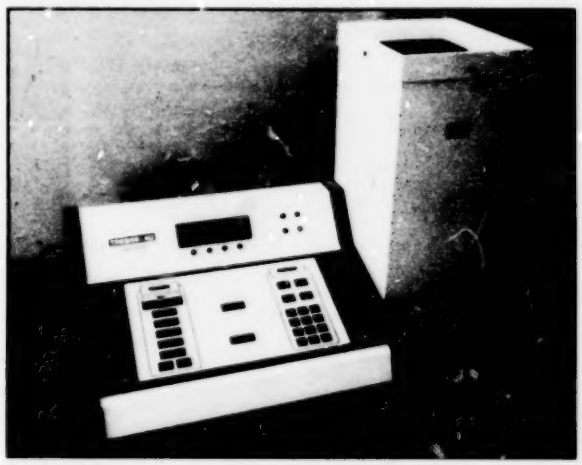


Figure 13
The Trebor GT-90 whole grain near-infrared transmittance analyzer.

1. Typical Banding Required to Achieve Segregation of Wheat into Portions of Designated Minimum Protein Content[1]

	Designated Minimum Protein Content[2], %			
Description of Band	11.5	12.5	13.5	14.5
Minimum Protein Content[2], %	—	12.0	13.2	14.5
Maximum Protein Content[2], %	11.9	13.1	14.4	—
Mean Protein Content[2], %	11.8	12.8	13.8	14.9
Proportion of Total Unload, %	10	30	40	20

[1] In this example, the mean protein content of all carlots in the shipment unloaded at the terminal elevator was 13.6%.
[2] Constant moisture basis of 13.5%.

NIR has replaced the Kjeldahl method (17) for practically all of this testing. Reference samples for protein content are generated annually at the GRL, based on the distribution of the new season's crop of western Canadian red spring wheat by grade. These are supplied to central protein testing laboratories at Thunder Bay and Vancouver where on-the-spot monitoring of all NIR instruments is carried out daily using KjelFoss automated Kjeldahl test equipment. The reference samples are used to verify the accuracy of the KjelFoss procedure relative to the GRL Kjeldahl procedure. The Kjeldahl laboratory (Figure 14) remains the standard used at the Commission for monitoring and calibration, but the use of NIR realizes annual savings of up to $500,000 to the Commission in operating and mail costs. The Grain Research Laboratory also provides a free NIR check sample and trouble-shooting service for all interested Canadian grain elevator companies and flour mills.

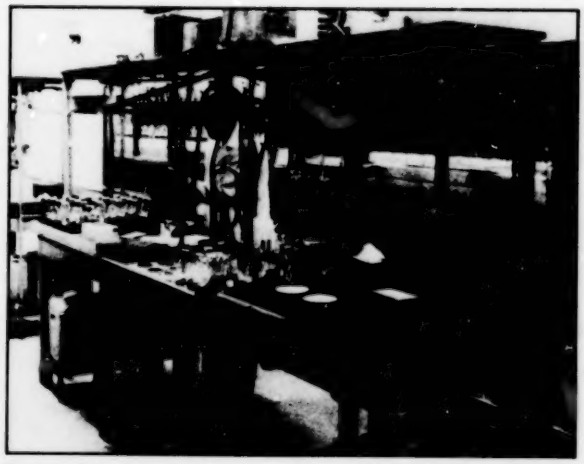


Figure 14
The titration bench at the Grain Research Laboratory Kjeldahl facility. The laboratory is capable of 960 macro-Kjeldahl tests per shift.

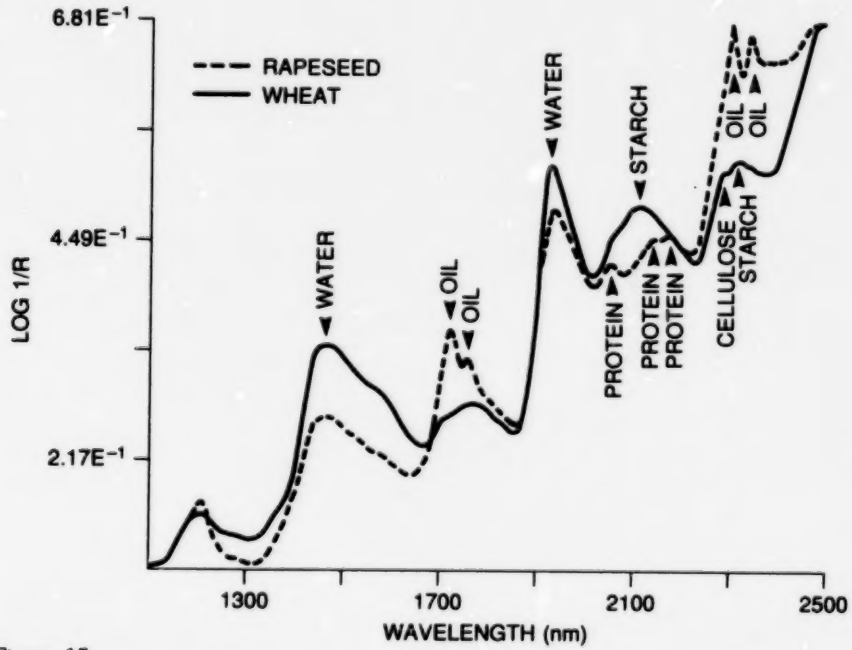


Figure 15
Near-infrared diffuse reflectance spectra of ground wheat and rapeseed. Protein absorbers occur at approximately 1690, 1980, 2054 and 2180 nm; oil at 1705, 1720, 2305 and 2345 nm; starch at 2100 and 2280 nm; cellulose at 2265 nm; and water at 1430 and 1930 nm.

Early studies in this field at the GRL included fundamental work in assigning wavelengths to the most important NIR absorbers for wheat constituents - including gluten, oil, starch and moisture (18). The wavelengths at which absorbance occurs and measurements can be made for the chief constituents of common agricultural/food commodities are illustrated in Figure 15, and those commonly used in discrete filter NIR instruments are listed in Table 2. A Pacific Scientific Research Composition Anlayzer, Model 6250 (Figure 16) was used in wavelength determination and mathematical treatment experiments, and a Model FQA51 Feed Quality Analyzer (Figure 17) and a DICKEY-john GAC III were used to verify the transfer of the research technology to commercial-type applications.

The use of NIR techniques to determine protein and moisture content in a wide range of commodities has been well-documented (14,19 to 21). NIR constants have been developed for the determination of the oil, protein and moisture content of rapeseed and soybeans (12), flaxseed and sunflower (unpublished), maize and millet (21), and for protein content of oats, sorghum and rice (unpublished). Protein content has also been determined by NIR in mixed feeds, where interactions between feed components caused by differences in particle size and shape and bulk density were found to be a major source of error (14). Lysine and several other amino acids have been determined in barley and wheat (22) and methionine has been determined in field peas (23). Near-infrared reflectance determinations of protein content in pulses such as lentil, chickpea, faba bean, field pea and pigeon pea have also been carried out (20).

2. Wavelength Filters Used in Discrete Filter NIR Analyzers[1]

Wavelength, nm	Principal Component Measurable
2310	Oil
2230	Reference
2180	Protein
2100	Starch (Protein)[2]
1940	Water
1680	Reference[3]

[1] DICKEY-john Grain Analysis Computer (GAC III) or "Instalab" series, Technicon InfraAlyzer Models 300 or 250, Percon Inframatic 8100.

[2] The 2100 nm filter is prominent in protein determination in cereal grains due to the strong negative relationship between protein and starch content.

[3] The 1680 nm filter serves as a reference for measurment of several constituents, and appears to compensate for fluctuations in particle size and distribution.

Figure 16
The Pacific Scientific Research Composition Analyzer Model 6250.

Figure 17
The Pacific Scientific Research Feed Quality Analyzer Model 51A.

Recent Developments

Current spectrophotometric analysis research at the GRL is aimed at developing adjuncts to the visual system presently used for grading all Canadian grains - adjuncts to provide information on the end-product utilization of the grains on the basis of chemical and physicochemical composition. Included are quality parameters such as: chlorophyll content, fibre content, kernel hardness, digestibility and energy potential.

Successful research has been undertaken into the analysis of whole (unground) seeds of wheat and rapeseed using a computerized spectrophotometer functioning in both the near-infrared and visible regions (Figure 18). Although oil and protein content were determined satisfactorily in whole rapeseed (24), more accurate chlorophyll content analysis was achieved by using ground seeds (25). Consequently, to determine chlorophyll in rapeseed, a DICKEY-john GAC was modified by replacing the 2310 and 2230 nm oil wavelength filters with 674 and 696 nm wavelength filters (25).

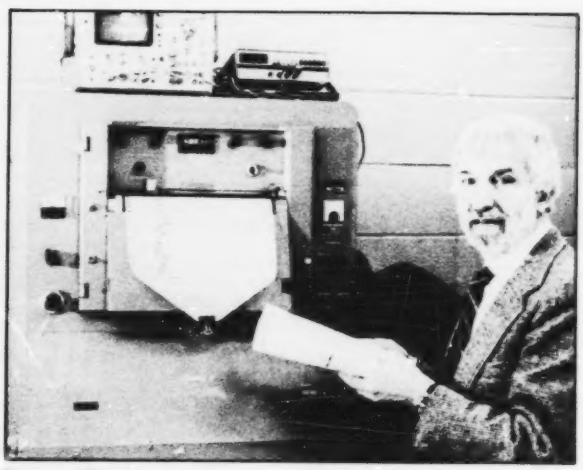


Figure 18
The Cary Model 17I computerized spectrophotometer.

Although barley is the most important feed grain in Canada, in some years large quantities of feed wheat become available and in Ontario about 7 million tonnes of maize are grown annually - much of which is used in the poultry and pig industries. The most important factors in feed grain utilization are the protein content and digestible energy. Calibrations have been developed for the NIR determination of protein and starch content and gross energy in the previously-mentioned three feed grains (unpublished), and research is in process for the development of calibrations for digestibility (pepsin/cellulase) which will be incorporated with the gross energy determination to give a NIR digestible energy value.

NIR technology is not limited to the determination of chemical constituents. A wheat hardness test has been developed, based on the principle that hardness affects the particle size of ground wheat. NIR is based on diffuse reflectance from a reflecting surface, and is very sensitive to particle characteristics. This sensitivity was exploited in the development of the NIR hardness technique which was tested in a worldwide collaborative study (26). A grinding-sieving procedure, the particle size index test, was used as the reference method for calibration (27). Another parameter which can be determined by NIR is flour ash content. There is no ash as such in flour - the mineral content is directly related to the degree to which the flour is contaminated with bran particles during milling. The mineral content is highly correlated to both the fibre and oil content of the flour (28) and by monitoring fibre content at a wavelength of 2336 nm, it is possible to determine the ash content. Recent work (29) indicates the possibility of predicting wheat strength (farinograph characteristics and remix loaf volume) by NIR. Table 3 summarizes constituents and parameters for which NIR calibrations have been developed or are being developed.

Studies at the Grain Research Laboratory have demonstrated the feasibility of using NIR techniques to determine protein content in whole wheat kernels (30) and field peas (31), and oil and protein content in whole rapeseed (32). The near-infrared transmittance (NIT) technique was found to give more accurate results for the determination of protein and moisture content (33) and the Canadian Grain Commission's Thunder Bay operation is currently using NIT instruments to test wheat for protein content. The results from a recent study into the determination of the moisture content of high moisture (over 30%) maize using a NIT instrument, the Trebor GT-30A (Figure 19), indicated that the accuracy of the NIT instrument was comparable with that of the Model 919 moisture meter currently in use and that readings exhibited less variability with differences in sample test weight.

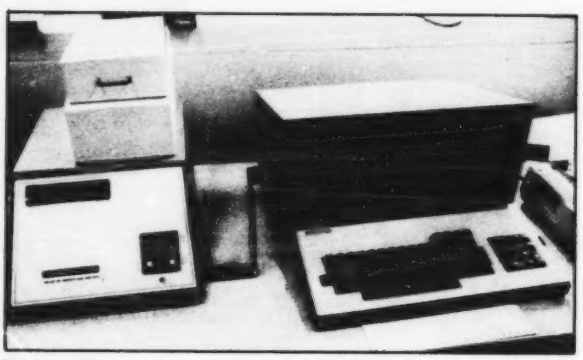


Figure 19
The Trebor GT-30 near-infrared transmittance moisture analyzer.

3. Status of NIR Research Into the Determination of Constituents Affecting the End Product Utilization of Some Canadian Grain and Seed Commodities

Common Milling Wheat	Durum Wheat	Feed Wheat, Barley, Maize	Oilseeds	Oilseed and Soybean Meal	Soybeans	Pulses
Moisture[1]	Moisture[4]	Moisture[1]	Moisture[2]	Moisture[2]	Moisture[2]	Moisture[2]
Protein[1]	Protein[4]	Protein[1, 5]	Protein[2]	Protein[2]	Protein[2]	Protein[2]
Kernel Hardness[4]		Lysine[2]	Oil[2]	Fibre[3]	Oil[2]	Lysine[2]
Gluten Strength[2]		S-amino Acids[2]	Chlorophyll[2]	Energy[2]		S-amino Acids[2, 6]
		Energy[2]	Fibre[2]	Digestibility[3]		
		Digestibility[3]		Digestible Energy[3]		
		Digestible Energy[3]				

[1] NIR analysis used in routine protein testing by the Canadian Grain Commission and Canadian grain companies and flour mills.
[2] NIR constants developed.
[3] NIR calibrations under investigation.
[4] Universal constants available for NIR determination.
[5] Barley only.
[6] Primarily methionine.

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LIAISON ACTIVITIES

VISITORS TO THE GRAIN RESEARCH LABORATORY

This year saw an increased demand for visits to the Grain Research Laboratory - ranging from short, general tours to comprehensive scientific and technical consultations with Laboratory research scientists, biologists, chemists and technologists. The following interest groups were typical of those represented: producers; university, community college and high school students; representatives of the grain trade (including missions from foreign countries); and grain quality analysts from Canada and abroad. As well, participants in Canadian International Grains Institute programs received practical and demonstration sessions at the Grain Research Laboratory under the supervision of GRL personnel.

Of the total number of 1,114 visitors accommodated, 832 were from within Canada while 282 came from the following 30 countries: Australia, Brazil, Bulgaria, Colombia, Egypt, England, Federal Republic of Germany, France, India, Indonesia, Iraq, Israel, Japan, Korea, Malaysia, Mexico, Netherlands, Norway, People's Republic of China, Peru, Philippines, Poland, Scotland, Singapore, Sri Lanka, Sweden, Taiwan, U.S.A., U.S.S.R. and Venezuela. In addition to the tours arranged on an "appointment" basis, the Grain Research Laboratory hosted, for one day in June, an "Open House" for Canadian senior grain trade representatives. This was well-received and allowed those who attended to become better acquainted with the functions and aims, programs and facilities of the GRL.

Dr. H.-O. Kim from Korea, via the University of Manitoba, completed her term of appointment to a National Research Council of Canada visiting fellowship - working with Dr. Williams in the Analytical Development Section. Miss C. Mayer of Centre Nationale de la Recherche Scientifique, Meudon, France spent 5 weeks working with Dr. MacGregor as part of an ongoing collaborative research program between the CNRS and GRL on starch degrading enzymes in cereal grains. Participants in the CIGI Latin American Milling and Baking Course spent considerable time at the GRL learning test procedures in the following areas of study: NIRS analysis, experimental milling, research baking and durum wheat research. For a CIGI program for senior officials of the Commodity Inspection Bureau, People's Republic of China, an intensive tour of the GRL facilities was provided - during which detailed demonstrations in the use of quality testing equipment and interpretation of results were organized. An orientation session on the functions and operations of the GRL was one of the items on the agenda for the visit of newly-appointed Assistant Commissioners of the Canadian Grain Commission, Messrs. A. Watson, M. Wakefield and W. Yurko. Mr. Eric Meuller, a technician with Dr. A. Tekauz of the Agriculture Canada Research Station in Winnipeg, was given a one-day training session in the Mycology Section on the identification of common *Fusarium* species found on wheat.

TECHNICAL AND CONSULTING VISITS MADE

As previously mentioned, market support is a major responsibility of the Grain Research Laboratory. Each year Laboratory scientists and technologists are called upon, in many instances at the request of the Canadian Wheat Board, to provide technical expertise to users of Canadian grains and oilseeds throughout the world.

In April and May, Dr. Tipples visited England and Portugal for technical discussions with buyers and processors regarding the quality of 1985-crop Canadian wheat. He also visited Switzerland to lecture at the Swiss school of milling at St. Gallen.

Dr. P. Williams again spent considerable time in Syria concerning the establishment and operation of grain quality testing laboratories in that country - a continuing commitment for technical consulting for ICARDA. In early summer, he was in Regina, Calgary and Lethbridge to liaise with grain company officials on the continued efficient receipt by the GRL of new-crop grain samples.

Dr. Matsuo and Mr. Paulley were part of a CIGI program in Indonesia in April - conducting seminars and baking demonstrations on the use of flour milled from Canadian

wheat. Dr. Preston was in France for meetings with several groups of people, including Mr. V. Suppeaux and Mr. J. Weiss of General Biscuits and grain merchant Mr. C. Gobert, concerning the suitability of Canadian wheat for the French baking industry.

Dr. Preston also visited several Far East locations this year: Indonesia - to discuss the quality of export shipments of Canadian wheat, and to participate with Bogasari Flour Mills personnel in quality testing of Canadian wheat to assess the potential of CWRS and CPS wheat for this market; Hong Kong - to discuss milling of Canadian wheat; and Korea - to discuss wheat quality requirements and specifications with Korean millers. In a joint-testing program arranged by the CWB in response to a request from Malayan Flour Mills, both Dr. Preston and Dr. Matsuo travelled to Malaysia to serve as the Canadian participants in these tests to evaluate the potential of Canadian wheat for the production of Malaysian bread and noodles.

In August Dr. Preston, as part of a CGC/CWB team, visited the Agriculture Canada Research Station in Swift Current, Saskatchewan to review with plant breeders the status of red and white "3M" wheat varieties; and in October he visited plant breeders at the University of Saskatchewan, Saskatchewan Wheat Pool and University of Alberta to discuss recent developments in wheat breeding programs.

In October, Dr. MacGregor visited several research laboratories in Japan, including those of Kirin Breweries, Asahi Breweries and Suntory Ltd.; and Dr. LaBerge was in the People's Republic of China for the CIGI-sponsored China-Canada Malting and Brewing Technology Symposium. Dr. Tipples made two trips to Japan following the autumn harvest of Canadian wheat: in November to discuss new-crop quality data with the Japanese Food Agency and with various grain and oilseed processing groups; in February to discuss the quality of export shipments of Canada Western Red Spring wheat.

During the last quarter, Dr. Tipples and Dr. Matsuo were in Singapore to participate in a CWB/CGC seminar on wheat quality; Dr. Preston was in Seoul, Korea as part of a CWB/GCG/CIGI mission for on-site testing of the milling and processing quality of Canadian wheat; and Dr. Tipples was in Toronto and Montreal to participate in Canadian Grain Commission meetings with grain dealer and producer groups.

Dr. LaBerge on location in the People's Republic of China to attend the CIGI-sponsored China-Canada Malting and Brewing Technology Symposium.

Scenes from the Grain Research Laboratory "Open House" which was held in June.

CONFERENCE AND MEETING ATTENDANCE

Agriculture Canada
- Advisory Committee on Variety Registration
  - Meeting in Ottawa, Ontario ..... R.R. Matsuo
- Expert Committee on Fats, Oils and Other Lipids
  - 1986 Meeting, Guelph, Ontario ..... J.K. Daun
- Western Expert Committee on Grain Quality
  - 1987 Meeting, Edmonton, Alberta ..... J.K. Daun, D.E. LaBerge, A.W. MacGregor, R.R. Matsuo, K.R. Preston, R. Tkachuk, K.H. Tipples
- Eastern Expert Committee on Grain Quality
  - 1987 Meeting, Quebec City, Quebec ..... K.H. Tipples
- Western Computer Users Meeting
  - Banff, Alberta ..... R. Tkachuk

American Association of Cereal Chemists
- Annual Meeting, Toronto, Ontario ..... J.E. Dexter, B.A. Marchylo, R.R. Matsuo, K.R. Preston, K.H. Tipples, R. Tkachuk, P.C. Williams
- Milling and Baking Technical Conference
  - Phoenix, Arizona ..... R.H. Kilborn

American Society of Brewing Chemists
- Annual Meeting, Tuscon, Arizona ..... D.E. LaBerge

Association of Official Seed Analysts/Society of Commercial Seed Technologists
- Annual Meeting, Minneapolis, Minnesota ..... L.A. Cooke

Association of Operative Millers
- District 8 Meeting, Toronto, Ontario ..... J.E. Dexter

Barley Centennial Celebrations
- Brandon, Manitoba ..... D.E. LaBerge

Barley Improvement Conference
- Minneapolis, Minnesota ..... D.E. LaBerge

Brewing and Malting Barley Research Institute
- Technical Committee Meetings
  - Winnipeg, Manitoba and Edmonton, Alberta ..... D.E. LaBerge
- Triennial Barley Improvement Meeting
  - Saskatoon, Saskatchewan ..... D.E. LaBerge, B.A. Marchylo

Canada Committee on Crop Production Services
- Meeting in Toronto, Ontario ..... K.H. Tipples

Canada-Japan Consultations on Canola
- Meeting in Ottawa, Ontario ..... J.K. Daun

Canadian Federation of Biological Societies
- Symposium in Guelph, Ontario ..... B.A. Marchylo

Canola Industry and Research Personnel Meeting
- Saskatoon, Saskatchewan ..... J.K. Daun

Chemical Institute of Canada Annual Conference
Saskatoon, Saskatchewan ..... T.W. Nowicki
China-Canada Malting and Brewing Technology Symposium
Beijing, Quindao and Shanghai,
People's Republic of China ..... D.E. LaBerge
Codex Alimentarius Commission
Meeting in Washington, D.C. ..... R. Tkachuk
Crop Quality Council Meeting
Manhattan, Kansas ..... K.R. Preston
International Association for Cereal Science and Technology
Symposium and Executive Committee
Meeting, Hamburg, FRG ..... K.H. Tipples
International Baking Industry Exposition
Vancouver, British Columbia ..... E. Mydlo
International Barley Genetics Symposium
Osaka, Japan ..... A.W. MacGregor
International Diffuse Reflectance Symposium
Chambersburg, Pennsylvania ..... P.C. Williams
International Standards Association
TC34/SC4 Committee Meeting, Budapest, Hungary ..... R. Tkachuk
Manitoba Agronomists
Annual Conference, Winnipeg, Manitoba ..... R.M. Clear
L.A. Cooke
Master Brewers' Association of the Americas
Annual Meeting, San Antonio, Texas ..... L.A. Cooke
Short Course on Brewing and Malting
Madison, Wisconsin ..... B.A. Marchylo
Phytopathological Society of Canada
Annual Meeting, Saskatoon, Saskatchewan ..... R.M. Clear
Regional Meeting, Winnipeg, Manitoba ..... R.M. Clear
Pittsburgh Conference and Exposition
Atlantic City, New Jersey ..... J.E. Kruger
Spring Wheat Quality Advisory Council Meeting
Minneapolis, Minnesota ..... R.R. Matsuo
Statistical Association of Manitoba
Annual Meeting, Winnipeg, Manitoba ..... J.C. Babb
Statistical Society of Canada
Annual Meeting, Banff, Alberta ..... J.C. Babb
Western Trace Organic Analysis
Annual Workshop, Vancouver,
British Columbia ..... T.W. Nowicki

COMMITTEE MEMBERSHIP

Canadian Grain Commission
- Eastern and Western Grain Standards Committees ..... K.H. Tipples

Agriculture Canada
- Advisory Committee on Variety Registration ..... R.R. Matsuo
- Canada Committee on Crop Production Services ..... K.H. Tipples
- Expert Committee on Fats, Oils and Other Lipids ..... J.K. Daun
- Western Expert Committee on Grain Quality ..... K.H. Tipples (Chairman)
  K.R. Preston
  R. Tkachuk
  - Subcommittee on Barley and Oats ..... D.E. LaBerge (Chairman)
    A.W. MacGregor
  - Subcommittee on Oilseeds and Special Crops ..... J.K. Daun (Chairman)
  - Subcommittee on Wheat ..... R.R. Matsuo (Chairman)
    K.R. Preston (Secretary)
    P.C. Williams

Agricultural Institute of Canada
- Associate Editor, Canadian Journal of Plant Science ..... K.R. Preston

American Association of Cereal Chemists
- Technical Committees:
  - Amylase Methods ..... J.E. Kruger (Co-chairman)
    A.W. MacGregor (Co-chairman)
  - Bread Baking Methods ..... R.H. Kilborn
    K.R. Preston
  - Experimental Milling ..... J.E. Dexter
  - Methods for Grain Testing ..... P.C. Williams
  - Near-infrared Reflectance ..... P.C. Williams
  - Pasta Products Analysis ..... J.E. Dexter
    R.R. Matsuo
  - Physical Testing Methods ..... R.H. Kilborn
    K.R. Preston
  - Quality Tests for Wheat and Flour ..... R. Tkachuk
  - Canadian Prairie Section ..... B.A. Marchylo (Chairman)
    L.A. Cooke (Secretary-Treasurer)
- Publications Committee ..... J.E. Kruger
- Board of Editors, Cereal Chemistry ..... J.E. Dexter
- Editorial Advisory Board, Cereal Foods World ..... A.W. MacGregor

American Oil Chemists' Society
- Seed and Meal Analysis Committee
  - Rapeseed and Canola Working Group ..... J.K. Daun (Co-ordinator)

Brewing and Malting Barley Research Institute
- Technical Committee ..... D.E. LaBerge

Canadian General Standards Boards
- Committee on Bakery and Cereal Products ..... R.R. Matsuo
- Committee on Canola Oil ..... J.K. Daun
- Committee on Canola Meal ..... J.K. Daun

Codex Alimentarius Commission, FAO, WHO
- Canadian Delegation ..... R. Tkachuk (Chairman)

Federal Interdepartmental Committee on
- Pesticides Check Sample Program:
  - Feeds/Grains Sub-program ..... T.W. Nowicki (Co-ordinator)

International Association for Cereal Science and Technology (ICC)
- Executive Committee, Technical Committee and General Assembly ..... K.H. Tipples
- Working Groups on:
  - Variety Identification by Electrophoresis ..... R. Tkachuk
  - Baking Tests ..... K.H. Tipples (Chairman)
  - Determination of Wet Gluten ..... K.R. Preston
  - Particle Size ..... P.C. Williams
  - Methods of Protein Determination ..... R. Tkachuk
  - Sampling ..... P.C. Williams
  - Near-infrared Technology ..... P.C. Williams

International Standards Organization
- Canadian Advisory Committee TC34/SC4 ..... K.H. Tipples (Chairman)
- Canadian Advisory Committee TC34/SC2 ..... J.K. Daun

Journal of Cereal Science
- Board of Editors ..... K.H. Tipples

Manitoba Sunflower Committee ..... J.K. Daun

Master Brewers' Association of the Americas
- Housing Committee for 1988 Convention ..... D.E. LaBerge (Chairman)

Microscopical Society of Canada
- Local Organizing Committee, Annual Meeting ..... L.A. Cooke (Treasurer)

Red River Community College
- Advisory Committee for Chemistry and Biochemical Technology ..... R. Tkachuk, D.E. LaBerge

University of Manitoba
- Adjunct Professors, Department of Plant Science ..... J.E. Kruger, A.W. MacGregor, R. Tkachuk, P.C. Williams

ORAL PRESENTATIONS

At Canadian International Grains Institute

K.H. Tipples
- Introduction to the Grain Research Laboratory (presented four times)
- Plant Breeding and the Market Place

R.M. Clear
- Molds Found on Canadian Grains and Their Effect on Grades
- *Fusarium* Head Blight in Canada

L.A. Cooke
- Preview of the Grading Factors Manual
- Dilemmas in Identifying and Distinguishing Visible Grading Factors

J.K. Daun
- An Examination of the Effects of Grading Factors on End-use Quality of Oilseed Products
- Oilseeds: New Developments in Canada - Technology and Marketing
- Effects of Grading Factors on End-use Quality of Canadian Grains - Oilseeds

C.J. Dempster
- Development of New Wheat Varieties in Canada: Screening for End-use Quality
- Relationship of Wheat Classes to End-use Quality

J.E. Dexter
- Effects of Grading Factors on End-use Quality of Canadian Grain - Wheat
- The Theory of Experimental Milling (presented three times)
- Relation of Wheat Class and Grade to End-use Quality (presented twice)

D.W. Hatcher, B.A. Marchylo and V.J. Mellish
- New Developments in Quality Measurement - Varietal Identification of Cereals

R.H. Kilborn and J.E. Kruger
- New Developments in Quality Measurement - Apparatus for Measurement of Sprout Damage

R.H. Kilborn
- Mixing: An Examination of the Role of Mixing and Mixer Design in Baking

J.E. Kruger
- Introduction to the Grain Research Laboratory (presented twice)
- Canadian Wheat: Properties, Functionality and End-uses

D.E. LaBerge
- New Developments in Quality Measurement - Image Analysis
- Malting and Brewing Technology
- Barley and Malt Analyses
- Biochemistry of Malting
- The Canadian Grading System for Barley
- Morphology and Composition of Barley
- Role of the Grain Research Laboratory Within the Canadian Grain Commission
- Factors Affecting End-use Quality of Barley

A.W. MacGregor
- Effects of Degrading Factors on Barley Utilization

R.R. Matsuo
- Pasta Goods Manufacturing
- Wheat: Properties, Functionality and End-uses

R.R. Matsuo and K.R. Preston
- Composition of Flour
- Types and End-uses of Wheat and Flour

B.A. Marchylo
- Introduction to the Grain Research Laboratory

V.J. Mellish
- Computer Image Analysis of 2-D Polyacrylamide Gel Protein Maps of Wheat Varieties and Their Mixtures

T.W. Nowicki
- Post-harvest Loss Control Pesticides
- Toxic Chemical Contaminants in Grain
- Quality Control and Assurance of Canadian Grain for Toxic Chemical Contaminants

K.R. Preston
- Ingredients and Additives in Bread Production
- Quality Characteristics of Canadian Wheat Classes

D.C. Sobering
- New Developments in Quality Measurement: Near-infrared Reflectance Spectroscopy

P.C. Williams
- Wheat: Properties, Functionality and End-uses

At Conferences, Meetings and Seminars

K.H. Tipples
- Small Baked Goods in North and South America. International Association for Cereal Science and Technology Symposium, Hamburg, FRG
- Wheat Research: Challenges for Today and Tomorrow. Department of Food Science, University of Manitoba, Winnipeg, Manitoba

J.C. Babb
- SIGSTAT and PC Matrix for the IBM-PC Microcomputer. Annual Meeting, Statistical Association of Manitoba, Winnipeg, Manitoba
- Statistical Consulting at the Grain Research Laboratory. Department of Statistics, University of Manitoba, Winnipeg, Manitoba

R.M. Clear and L.A. Cooke
- Seed Analyst Seminar. Manitoba Regional Seed Laboratory, Winnipeg, Manitoba

R.M. Clear

Mycological Analysis of Wheat Infected with Head Blight. Regional Meeting, Phytopathological Society of Canada, Winnipeg, Manitoba

L.A. Cooke

Barley Nobody Malts. Winnipeg Brewmasters' Conference, Winnipeg and Annual Convention, Master Brewers' Association of the Americas, San Antonio, Texas

Insect Damage in Cereal Grain Samples. Agriculture Canada Winnipeg Research Station Seminar Series, Winnipeg, Manitoba

J.K. Daun

Analysis of Phospholipids in Canola Oil by TLC. Technological Session, Expert Committee on Fats, Oils and Other Lipids, Guelph, Ontario

Chlorophyll in Canola. University of Saskatchewan, Saskatoon, Saskatchewan

J.E. Dexter

Effect of Test Weight on Durum Wheat Quality. Annual Meeting, AACC, Toronto, Ontario

Quality of the 1986 Canadian Wheat Crop. Meeting of District 8, Association of Operative Millers, Toronto, Ontario

D.E. LaBerge

Changes in Isoelectric Properties of Beta-amylase Enzymes of Barley During Malting. Annual Meeting, American Society of Brewing Chemists, Tuscon, Arizona

A Possible Rating System for Malting Barley. Triennial Meeting, Brewing and Malting Barley Research Institute, Saskatoon, Saskatchewan

A.W. MacGregor

Amylase Activity. Cereal Carbohydrate Research and Utilization Seminar. Purdue University, Indiana

Cereal Alpha-amylases and Their Action on Starch. Department of Food and Nutrition, Osaka City University, Japan

Development and Maturation of Kernel Tissues - A Microscopy Study. International Barley Genetics Symposium, Osaka, Japan

Grain Research: Progress in Research on Cereal Enzymes. Department of Food Science, University of Manitoba, Winnipeg, Manitoba

Six lectures on barley technology. Department of Plant Science, University of Manitoba, Winnipeg, Manitoba

B.A. Marchylo

Alpha-amylase Composition in Germinating Cereal Grains. Annual Meeting, AACC, Toronto, Ontario

Structure and Composition of Barley. Short Course on Brewing and Malting, MBAA, Madison, Wisconsin

Biochemistry of Malting. Short Course on Brewing and Malting, MBAA, Madison, Wisconsin

Studies of Cereal Storage Proteins Using HPLC. Symposium, Canadian Federation of Biological Studies, Guelph, Ontario

R.R. Matsuo

A Rapid Test for the Estimation of Spaghetti Cooking Quality. Annual Meeting, AACC, Toronto, Ontario

T.W. Nowicki

Chemical Toxicants in Grains. Annual Conference, Chemical Institute of Canada, Saskatoon, Saskatchewan

K.R. Preston

The Canadian Wheat System. Kansas State University, Manhattan, Kansas

Quality of 1986 Canada Eastern New Crop Wheat. Meeting of Ontario Wheat Producers, Kincardine, Ontario

La qualité du blé canadien. Meeting of Association nationale de la meunerie francaise, Quebec City, Quebec

R. Tkachuk

High Resolution Two-dimensional PAGE Separation of Wheat Proteins. Annual Meeting, AACC, Toronto, Ontario

Image Analysis of Two-dimensional Polyacrylamide Gel Protein Maps of Wheat Varieties and Their Mixtures. Annual Meeting, AACC, Toronto, Ontario

P.C. Williams

On the Testing of Strength in Wheat by NIR. Annual Meeting, AACC, Toronto, Ontario

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M141 PRESTON, K.R., KRUGER, J.E. Mobilization of Monocot Protein Reserves During Germination. In *Plant Proteolytic Enzymes*, pub. CRC Press, 1984.

M143 PRESTON, K.R. Utilization of Medium and High Protein Red Spring Wheat: Wheat Production in Canada. Proc. Can. Wheat Prod. Sym., 535-543, 1986.

M144 PRESTON, K.R., MATSUO, R.R., DEXTER, J.E., TWEED, A.R., KILBORN, R.H., TULLY, D. The Suitability of Various Canadian Wheats for Steamed Bread and Noodle Processing for the People's Republic of China. JCIFT 19(3):114-120, 1986.

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PRESTON, K.R., KILBORN, R.H. Basic Straight Dough Long Fermentation Baking Procedure. In *Methods of the American Association of Cereal Chemists*, pub. by the AACC, 1986.

CHAPTERS IN BOOKS

TIPPLES, K.H. Testing Candidate Wheat Cultivars for Quality. In *Wheat Production in Canada*, published by the Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, Saskatchewan, 1986. Pages 500 to 511.

PRESTON, K. Utilization of Medium and High Protein Red Spring Wheat. In *Wheat Production in Canada*, published by the Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, Saskatchewan, 1986. Pages 535 to 543.

MATSUO, R.R. Utilization of Durum Wheat. In *Wheat Production in Canada*, published by the Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, Saskatchewan, 1986. Pages 554 to 563.

PERIODICAL PUBLICATIONS

Fifty-ninth Annual Report

1985-86 Report of the Grain Research Laboratory

Cargo Bulletins

Red Spring Wheat editions are published in an English-French-German-Spanish version, an English-Japanese version (suffix "J") and an English-Chinese version (suffix "C"). Amber Durum Wheat editions are published in an English-French-German-Italian version.

230 Quality of Canadian Grain Exports 1985-86, Red Spring Wheat, second quarter (Nov. 1 to Jan.31)

231 Quality of Canadian Grain Exports 1985-1986, Amber Durum Wheat, first and second quarters (Aug. 1 to Jan. 31)

232 Quality of Canadian Grain Exports 1985-86, Red Spring Wheat, third quarter (Feb. 1 to Apr. 30)

233 Quality of Canadian Grain Exports 1985-1986, Red Spring Wheat, fourth quarter (May 1 to July 31)

234 Quality of Canadian Grain Exports 1985-1986, Amber Durum Wheat, third and fourth quarters (Feb. 1 to July 31)

— Quality of Canadian Rapeseed and Flaxseed Cargoes, 1985-1986, Crop Year

235 Quality of Canadian Grain Exports 1986-1987, Red Spring Wheat, first quarter (Aug. 1 to Oct. 31)

Crop Bulletins

168 Quality of 1986 Canadian Wheat

168A Quality of 1986 Canadian Wheat, Supplementary Edition

169 Western Canadian Oilseeds 1986

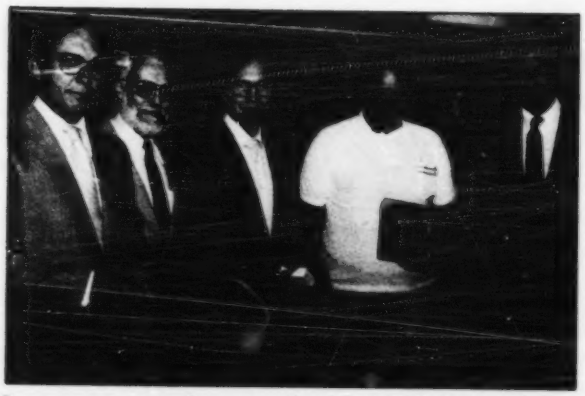
— Quality of Western Canadian Rapeseed and Flaxseed, 1986 New Crop, Preliminary Report

— Quality of Western Canadian Rapeseed, 1986 New Crop, Final Report

— Quality of Western Canadian Flaxseed, 1986 New Crop, Final Report

— Quality of 1986 Canadian Soybean Crop

STAFF



Long-service awards received by (L to R): Mr. R.H. Kilborn, Dr. C.J. Dempster, Mr. H.E. Hughes — for 35 years' service; Mr. E. Mydlo — for 25 years' service. Presentation was made by Dr. K.H. Tipples.

Presentation of a second suggestion award to Mr. W. Podolak. (L to R: Mr. W.J. O'Connor, Executive Director of the Canadian Grain Commission; Mr. G. Leith, Chief Commissioner; Mr. W. Podolak; Dr. K.H. Tipples, Director of the Grain Research Laboratory.)

K.H. Tipples, B.Sc., Ph.D.	Director
D.J. Ramsay	Secretary
N.H. Barchuk, B.Sc	Special Assistant to the Director (Research)

Administration

D.E. Routley	Assistant Director (Administration)
K.A. Tait	Office Manager
G.A. McLean, B.M. Mercer, M.J. Pewarchuk, M.C. Cyr	Clerks
S.L. Wiebe	Word Processing
M.E. Lick, Dipl. A.A., V.P. McKinnon	Secretaries
S. Dare, C. Kennedy*	Casual Assistants

Analytical Development and Services

P.C. Williams, B.Sc., Ph.D.	Research Scientist
J.A. Panford, B.S.A., M.Sc.	Chemist
W. Podolak, P.A. Starkey	Senior Technologists
C.J. Ashley, H.M. Cordeiro, Dipl. T., F.Y. Lim, L.G. Oneschuk, C.M. Panting, D.C. Sobering, B.Sc., R.K. Brady, D. Parent, Dipl.T., T. Boomer, G.R. Hennessey, C. Lactin, B.Sc., E. Padilla*, T. Pilley, B.Sc., D.S. Saydak, B.S.A., J.P. Yau, B.Sc., M.Sc.	Scientific Support
W. Aarts	Casual Assistant

Barley - Basic Research

A.W. MacGregor, B.Sc., Ph.D.	Research Scientist
J.E. Morgan, B.Sc.	Chemist
L.G. Dushnicky, B.Sc.	Senior Technologist
S.W. Schroeder, B.Sc.	Scientific Support

Grain Biology and Malting Barley Applied Research

D.E. LaBerge, B.Sc., M.Sc., Ph.D.	Research Scientist
L.A. Cooke, B.S.A.	Biologist
R.M. Clear, B.S.A.	Mycologist
D.E. Langrell, B.Sc., A.D. Mitchelson, M.M. Stethem, J.R. Bethune, S.K. Patrick, B.Sc.	Scientific Support
T. Cho**	Casual Assistant

Cereal Protein Research

B.A. Marchylo, B.Sc., M.Sc., Ph.D.	Research Scientist
K.A. Handel, Dipl.T., P.A. Funk, Dipl. T.	Scientific Support
A. Dufresne**	Casual Assistant

Breadwheat Quality Studies

K.R. Preston, B.Sc., M.Sc., Ph.D.	Research Scientist
B.C. Morgan, B.Sc.	Chemist
E. Mydlo, G.T. Kawamoto, B.Sc. (Agric.), L.W. Minty, E.D. Lysenko, B.P.E., I.H. Phillips, B.Sc., C.K. Taplin	Scientific Support
M. Daly*, R. Baert**	Casual Assistants

Breadmaking Research

R.H. Kilborn	Senior Technologist
E.J. Gander, F.G. Paulley, L.H. Pelletier	Scientific Support
L. Enns	Casual Assistant

Publications and Durum Wheat Research

R.R. Matsuo, B.Sc., Ph.D., M.C.I.C.	Research Scientist
P.R. March, B.Sc.	Chemist
R.W. Daniel	Senior Technologist
H. Zimberg, D.M. Chance, B.I.D., M. Lymych, S. Beauchemin, Dipl. Ad. A.	Scientific Support
R. Roscoe	Casual Assistant

Flour Milling

J.E. Dexter, B.Sc., M.Sc, Ph.D.	Research Scientist
D.G. Martin	Senior Technologist
N.M. Edwards, Dipl. T., B.Sc., J.J. Lachance, R.G. Desjardins, P.V. Harbun, G. Holowka, B.A., D.R. Ouellette, J.N. Burrows, B.S.A.	Scientific Support

Laboratory Services

C.J. Dempster, B.Sc., Ph.D.	Chemist
J.C. Babb, B.Sc., M.Sc.	Biometrician
H.E. Hughes	Senior Technologist
G.G. Baker, R.J. Wallis	Scientific Support
A.R. Armstrong, C. Rebizant	Clerks
B. Vane, M. Craig**	Casual Assistants

Oilseeds

J.K. Daun, B.Sc., M.Sc., Ph.D., M.C.I.C.	Research Scientist
L.D. Burch*, B.S.A.., D.R. DeClercq, B.Sc., C.T. Thorsteinson, B.Sc.	Chemists
P.B. Mazur, K.M. Clear, B.S.A., H.K. Howard, B.A. Misener	Scientific Support

Residue Analysis

T.W. Nowicki, B.Sc.	Chemist
D.G. Gaba, B.Sc.	Chemist
J.W. Thorsteinson, Dipl. T., W.H. Harnden, B.S.A.	Scientific Support
A. Holmberg	Casual Assistant

Wheat Chemistry

R. Tkachuk, B.A., M.Sc., Ph.D., F.C.I.C.	Research Scientist
L.J. Macri, B.Sc., M.Sc.	Chemist
S. Gowan, Dipl.T., S. Lowe, B.Sc.	Scientific Support

Wheat Enzymes

J.E. Kruger, B.Sc., M.Sc., Ph.D., M.C.I.C.	Research Scientist
D.W. Hatcher, B.Sc., M.Sc.	Chemist
L.J. Morris, D.A. Daniel, Dipl. T.	Scientific Support
J. Spicer	Casual Assistant

Wheat-Varietal Identification

V.J. Mellish, B.Sc.	Chemist
G.G. Bell, Dipl. T., K. Jarrin	Scientific Support

*Separated from staff during this reporting period.
**Career-oriented Summer Employment Program (COSEP).